Capstone Design CENE 486c - Spring 2006

Portable Water Treatment System

Final Design Document

Submitted By:



April 25, 2006



Paul Gremillion, Ph.D., P.E. Professor of Civil & Environmental Engineering Peterson Hall, Room 217 Northern Arizona University South San Francisco Street Flagstaff, AZ 86011

Portable Engineering Solutions Northern Arizona University Emerald City, Room 165 South San Francisco Street Flagstaff, AZ 86011

RE: 100% Submittal of Capstone Design Report

Dear Doctor Gremillion:

You will find enclosed the final design document for the Portable Water Treatment System as requested. Items that were not included in the 90% design report are certified laboratory results and conclusions. Contents include design selection, hydraulic calculations, prototype construction, testing results, and problems encountered.

If there are any questions, suggestions, and/or comments please feel free to contact any member of our team. The team members of Portable Engineering System are:

- o Mark Abrahams mba9@dana.ucc.nau.edu (928) 214-7428
- o Michael Brown mb99@dana.ucc.nau.edu (928) 606-6622
- o Noah Schmadel nms2@dana.ucc.nau.edu (928) 699-5580

Conducting research, constructing the prototype, and performing testing has been intellectually stimulating and a great learning opportunity. We have produced a great product and hope it will be used to benefit the university. Thank you for your help and professional input.

Sincerely,

Noah Schmadel On behalf of PES April 25, 2006



TABLE OF CONTENTS

1.0	INTRODUCTION
1.1	BACKGROUND
1.2	SCOPE OF PROJECT
1.3	GOALS2
1.4	OBJECTIVES2
1.5	CURRENTLY AVAILABLE TECHNOLOGY
2.0	WATER TREATMENT THEORY
2.1	Reverse Osmosis Theory5
2.2	SEDIMENT FILTRATION
2.3	ACTIVATED CARBON FILTRATION8
2.4	ULTRAVIOLET DISINFECTION8
3.0	DESIGN10
3.1	DESIGN CONCEPTS10
3.2	DECISION MATRIX12
3.3	PATENT SEARCH12
3.4	Hydraulic Design13
3.5	Hydraulics Calculations16
3.6	ELECTRICAL DESIGN
3.7	PROTOTYPE CONSTRUCTION
4.0	WATER ANALYSIS
4.1	WATER QUALITY STANDARDS27
4.2	TESTING AND SAMPLING
4.3	SOURCE WATER QUALITY
5.0	RESULTS
5.1	COST AND WEIGHT
5.2	PRODUCTION RATES
5.3	WATER QUALITY
5.4	PROBLEMS ENCOUNTERED
5.5	IMPROVEMENTS FOR FURTHER DEVELOPMENT40
6.0	CONCLUSION
7.0	BIBLIOGRAPHY & WORKS CITED42
APPEN	DIX A - COMPONENT TECHNICAL SPECIFICATION
APPEN	DIX B - HYDRAULIC DATA
APPEN	DIX C - ELECTRICAL SYSTEM
APPEN	DIX D - ANALYTICAL PROCEDURES AND RESULTS

- APPENDIX E CHAIN OF CUSTODY RECORD
- APPENDIX F OPERATING INSTRUCTIONS
- APPENDIX G PARTS INVENTORY



FIGURES

FIGURE 1.1 - PHOTOGRAPHS OF COMMERCIALLY AVAILABLE WATER TREATMENT SYSTEMS 4	ļ
FIGURE 2.1 - RELATIVE SIZE OF COMMON MATERIAL AND CORRESPONDING FILTRATION TECHNOLOGY 5	;
FIGURE 2.2 - THE ULTRAVIOLET WAVELENGTHS DEPICTED ON THE ELECTROMAGNETIC SPECTRUM)
FIGURE 3.1 - FOUR DESIGN CONCEPTS FOR PORTABLE WATER TREATMENT SYSTEM	
FIGURE 3.2 - HYDRAULIC SYSTEM SCHEMATIC	;
FIGURE 3.3 - DIAGRAM AND PHOTOGRAPH OF RO MEMBRANE XLE-2521	ļ
FIGURE 3.4 - PHOTOGRAPH OF CONTROL UNIT ELECTRONICS)
FIGURE 3.5 - SCHEMATIC OF THE ELECTRICAL CONTROL UNIT	
FIGURE 3.6 - PHOTOGRAPHS OF THE TESTING PROTOTYPE	ļ
FIGURE 3.7 - ORTHOGRAPHIC DRAWING OF FINAL PROTOTYPE	;
FIGURE 3.8 - PHOTOGRAPH OF THE FINAL PROTOTYPE DURING TESTING	j
FIGURE 3.9 - PHOTOGRAPH OF THE FINAL PROTOTYPE AFTER AESTHETIC IMPROVEMENTS	j
FIGURE 4.1 - GRAPH OF WATER QUALITY IN SOURCE WATERS	2
FIGURE 5.1 - TDS VALUES FROM SOURCE WATER AND DIFFERENT MODES OF OPERATION	ļ
FIGURE 5.2 - TURBIDITY VALUES FROM SOURCE WATER AND DIFFERENT MODES OF OPERATION	;
FIGURE 5.3 - ALKALINITY VALUES FROM SOURCE WATER AND DIFFERENT MODES OF OPERATION	;
FIGURE 5.4 - pH VALUES FROM SOURCE WATER AND DIFFERENT MODES OF OPERATION	j
FIGURE 5.5 - HARDNESS VALUES FROM SOURCE WATER AND DIFFERENT MODES OF OPERATION	j
FIGURE 5.6 - AVERAGE COD VALUES FROM SOURCE WATER AND DIFFERENT MODES OF OPERATION	1
FIGURE 5.7 - COPPER VALUES FROM SOURCE WATER AND DIFFERENT MODES OF OPERATION	'
FIGURE 5.8 - ARSENIC VALUES FROM SOURCE WATER AND DIFFERENT MODES OF OPERATION	;
FIGURE 5.8 - ARSENIC VALUES FROM SOURCE WATER AND DIFFERENT MODES OF OPERATION	;

TABLES

TABLE 3.1 -	- DECISION MATRIX USED TO CHOOSE FINAL DESIGN	12
TABLE 3.2 -	- RO SELECTION	14
TABLE 4.1 -	- EPA NATIONAL DRINKING WATER STANDARDS	27
TABLE 4.2 -	- SAMPLE RESULTS OF SOURCE WATER	32
TABLE 5.1 -	- PERCENTAGE REDUCTION FOR EACH TYPE OF ANALYSIS	39



"Water, water, every where Nor any drop to drink."

> -Samuel Taylor Coleridge's The Rime of the Ancient Mariner

1.0 Introduction

Clean and safe water is vital for human survival. Treatment of water for human consumption has been a challenge throughout the history. For many citizens in the United States obtaining clean water is as simple as turning the faucet or opening a bottle of water; however, there are circumstances where water is plentiful but not safe for consumption. Those circumstances range from river rafting the Colorado River to cleaning up of polluted water in the aftermath of a natural catastrophe.

1.1 Background

River rafters require large amounts of potable water for extended river trips but lack the capacity to carry this amount of water with them. Water from the river is available but high concentrations of microorganisms can cause dysentery and other sicknesses. A self-contained portable water treatment unit would give river rafters access to safe potable water from perennial sources such as the Colorado River without having to sacrifice cargo space.

Victims of natural catastrophe often require fresh water that may not be available after existing infrastructures fail. Recent examples where freshwater was unavailable to victims include the Sumatra Tsunami of 2004 and Hurricane Katrina destruction to the Gulf coast during 2005. A self-contained portable water treatment system with the option of having an emergency power supply would provide victims of natural disasters with a clean supply of safe potable water that will save lives.

1



1.2 Scope of Project

The Portable Water Treatment System developed by Portable Engineering Solutions (PES) was designed and a prototype constructed. The system was designed to be user-friendly, reliable, self-contained, portable, inexpensive, and yet treat a variety of water sources to drinking water standards.

1.3 Goals

PES had the following goals for the Portable Water Treatment System:

- The water treated by the system must meet or exceed all drinking water standards
- The rate of water delivery must meet or exceed any systems currently in use
- The final cost of system must be similar to or less than other available systems
- Maintenance of unit must be minimal, relatively inexpensive, and limited to changing any filters or chemicals
- The results of the water treated by system would be verified by a certified laboratory

1.4 Objectives

The Portable Water Treatment System was designed to meet the following objectives:

- To develop a portable water treatment unit to produce safe drinking water from natural water bodies
- To provide disinfection for elimination of harmful microscopic organisms
- To be portable with a low total weight so that the system can be moved by one person
- To produce treated water while onboard a waterborne vessel
- To have a power supply that will provide enough power for the unit for ten days at a minimum of 100 gallons per day



1.5 Currently Available Technology

There are several commercial water treatment units currently available to the public. Examples of the currently available technology for the treatment of drinking water are:

- **The Aqua-Partner** The system uses a 5-micron screen pre-filter followed by a 0.5-micron carbon block filter. Disinfection is performed by ultraviolet light. A fully charged battery is capable of running the unit at 1.0 gallon per minute for 1.25 to 1.5 hour. An optional solar panel is available to recharge the battery between uses. The total weight of the unit without the battery is 15 pounds and costs \$1,064. A photograph of the system can be seen in Figure 1.1. (Happy Camper, 2005)
- **The Trekker** The system is manufactured by Noah Water System and is used for emergency water production. The system uses a 4-stage treatment process and disinfects by using Ultraviolet (UV) light. An external 12-volt power supply must be supplied to energize the unit. The system can produce 1.0 gallon of filtered water per minute, weighs 26.5 pounds, and costs approximately \$800. A photograph of the system can be seen in Figure 1.1. (Noah Water Systems, 2005)
- SWRO-225 The smallest desalination system available from Dime Water, Inc., the system is designed to treat seawater by a reverse osmosis (RO) process. The unit does not include disinfection but relies on the RO process to remove microscopic organisms. The unit has a small electric generator with fuel tank sized for 10 hours of operation. The unit can produce 0.15 gallons of drinking water per minute, weighs 80 pounds, and costs \$8,950. A photograph of the system can be seen in Figure 1.1. (Dime Water, 2005)
- Aquamiser A216S Designed for installation on personal yachts, the system is designed to treat seawater by a RO process. The system uses a 5-micron filter, 1-micron filter, and a RO membrane. System operates automatically and performs back flushes to extend filter life. The unit does not include disinfection but relies on the RO process to remove microscopic organisms. The unit can produce 0.16 gallons of drinking water per minute, weighs 150 pounds, and costs \$7050. A photograph of the system can be seen in Figure 1.1. (excel water, 2005)





Figure 1.1- Photographs of commercially available water treatment systems A) Aqua-Partner B) The Trekker C) Dime System SWRO-225 D) Aquamiser A216S

After extensive research, it was discovered that no publicly available portable water treatment system fulfilled the objectives and goals. Many of the less expensive and more transportable treatment units simply filter the water, while the more expensive and less transportable units treat the water with RO technology.



2.0 Water Treatment Theory

Prior to finalizing the design for the Portable Water Treatment System research was conducted to determine the best available technology for achieving the goals and objectives. Preliminary research indicated the final design may contain RO treatment, conventional filtration, and ultraviolet disinfection.

2.1 Reverse Osmosis Theory

Reverse osmosis, also known as hyperfiltration, is a highly selective filtration process. Discovered by Dennis Chancellor in the 1970s, RO has become an increasingly popular water treatment technology for commercial, military, residential, and municipal applications. One common application of RO is to purify chemicals such as ethanol and glycol. A second and wider use of RO technology is for purifying drinking water. RO is a process that effectively removes salts and other constituents resulting in improved color, taste, and/or physical properties of the drinking water. Figure 2.1 shows the relative size of materials and the operation range for RO technology and other filtration technologies. (Cheremisinoff, 2002; Manahan, 2001)

	Ionic Range Molecular Range Macro Molecular Range Micro Particle Range N	1acro Particle Range
Micrometers (Log Scale)	0.001 0.01 0.1 1.0 10	100 1000
Angstrom Units (Log Scale)	ָוֹם 10 100 1000 10 ⁺ 10 ⁺ 10 ⁺ 	10° 10 ^{7.} 8 2 3 5 8 2 11 1 1 1 11 1
Approx. Molecular Wt. (Saccharide Type-No Scale)	e) 100 200 1000 10,000 20,000 100,000 500,000	
Polativo	Albumin Protein Yeast Cells Aqueous Salts Carbon Black Paint Pigment Atomic Radius Sugar Virus A.C. Fine Test Dust	in sint Beach Sand Granular Activated Carbon
Size of Common Materials	Metal Ion Synthetic Dye Colloidal Silica Blue Indigo Dye Blood Cells Huma	lon Ex. Resin Bead
	Gelatin Coal Dust	Mist
Process For Separation	REVERSE OSMOSIS ULTRAFILTRATION PARTICLE FI	LTRATION

Figure 2.1 - Relative size of common material and corresponding filtration technology (Cheremisinoff, 2002)



RO theory relies on osmosis and ionic repulsion. Osmosis is defined as the "movement of a solvent through a semi-permeable membrane (as of a living cell) into a solution of higher solute concentration that tends to equalize the concentrations of solute on the two sides of the membrane." Osmosis is related to diffusion, which describes the tendency of molecules to move in solution until the molecules are uniformly distributed. For example, a chemical will tend to flow into pure water until all the water has the same concentration of the chemical. An applied pressure to the more concentrated solution results in a reversed osmotic flow. Pure water is forced through the semi-permeable membrane into the less concentrated solution. Suspended solids are blocked by mechanical filtration and dissolved solids are chemically repulsed by the membrane surface. RO differs from other traditional filtration technologies such as ultrafiltration / microfiltration by the following means: (Cheremisinoff, 2002; Eisenberg, 1986)

- RO has the ability to concentrate dissolved salts
- RO uses chemical and mechanical processes not based on size isolation
- RO does not tolerate significant concentrations of suspended solids
- RO requires higher pressures
- RO has lower flow rates
- RO membranes can not normally be reverse flowed to clean the media

RO process normally uses a semi-permeable membrane that allows permeate, the fluid that has been purified, to pass but prevents contaminants from passing. The contaminants that fail to pass concentrate on one side of the membrane. RO process is capable of rejecting bacteria, salts, sugars, proteins, particles, dyes, and other constituents. The rejection of a chemical species by RO process is best observed when the species posses the following characteristics: (Cheremisinoff, 2002; Eisenberg, 1986)

- High Degree of Dissociation
- High Ionic Charge
- High Molecular Weight
- Non-polar Substance
- High Degree of Hydration
- High Degree of Molecular Branching



The separation of ions with RO is aided by amount of charge possessed by the particles. The dissolved ions that carry a charge are more likely to be rejected by the membrane than those that are not charged. Larger charges on contaminant particles result in better rejection of the particle. Generally, salts with high charges are rejected more readily than organics ions that lack charge. Multi-charged ions are rejected at rates exceeding 99 percent and single-charged ions have rejection rates in the range of 90 to 96 percent. RO will also reject neutral solutes but at lower removal rates. (Cheremisinoff, 2002)

RO requires a driving force in the form of differential pressure to ensure flow through the membrane. Higher differential pressure results in a larger driving force and generally a corresponding increase in flow rate. The minimum differential pressure required to drive the process is determined by the composition of the feed solution and the membrane pore size. As the concentration of contamination of feed water on one side of the membrane increases, the differential pressure across the membrane required to continue filtration increases. (Cheremisinoff, 2002)

The RO process normally operates continuously. The RO membrane is enclosed in a pressure vessel and the feed stream is pumped through the vessel under pressure where it is separated into a clean water permeate stream and a concentrated chemical stream by selective permeation. The efficiency of removal by RO is controlled by feed pressure, feed rate, and concentrate rejection rate. Additionally, as the concentration gradient increases, the rejection efficiency decreases. (Cheremisinoff, 2002; Tchobanoglous *et al*, 2003)

The RO process can use cross-flow or dead-end technology. Cross-flow technology allows the RO membrane to continually clean itself by disposing of the higher concentrated liquid that does not pass through the RO membrane. Cross-flow filtration commonly has the source liquid to be filtered as it is pumped across the membrane parallel to its surface. Dead-end technology requires all of the feed solution to be forced through the membrane by an applied pressure. Eventually the source water is concentrated to the extent that there is no flow through the membrane. The concentrated feed is then removed and replaced with a fresh feed source. (Cheremisinoff, 2002; Tchobanoglous *et al*, 2003)



2.2 Sediment Filtration

Sediment filtration uses mechanical rejection to stop suspended solids from continuing though the filter. Any particle that is larger than the pore size is not allowed to pass through the filter media. Sediment filters are best utilized by orientating the flows from large to smaller pore size. The life of an individual filter in a multiple filter system can be extended by orientating the larger pore diameter filters prior to small pore diameter filters. Removing large particles sooner in the flow stream minimizes the chance that small pores will be clogged by debris. Various types of sediment filters are available, but the least expensive are made of paper or cotton. One disadvantage of sediment filtration is that once the filters pores are plugged by debris the filter must be cleaned or replaced. (Cheremisinoff, 2002; LaGrega, 2001)

2.3 Activated Carbon Filtration

Granular or block activated carbon filters effectively remove organic contaminants by the process of absorption. The activated carbon has numerous cavities that have been washed by a process of steam cleaning. Activated carbon filtration has the ability to remove suspended matter, pesticides, Polychlorinated Biphenyls (PCBs), and Trihalomethanes (THM) including chloroform. Activated carbon treatment does not affect non-organic chemicals such as sodium, nitrates, fluoride, and heavy metals. The main disadvantage of using activated carbon filtration is that the cavities can become clogged requiring reactivation or replacement. A second disadvantage of activated carbon filtration is that biological growth can occur in the media which can be released during a hydraulic shock. (Cheremisinoff, 2002; LaGrega, 2001)

2.4 Ultraviolet Disinfection

Ultraviolet (UV) light irradiation provides disinfection through the transference of electromagnetic energy at a germicidal wavelength that is absorbed by a microorganism's genetic material. UV light lies on the electromagnetic spectrum above the frequency to be categorized as X-rays but below that required for visible light as can be seen in Figure 2.2. The UV wavelengths have the ability to damage cells of microscopic organisms by structurally altering the DNA molecule or RNA in viruses. The damage can kill the cell or prevent proper reproduction. Byproducts produced by exposing water to the energy dose



required for the disinfection (50 to 140 mJ/cm²) are normally harmless or broken down to more innocuous forms. (Tchobanoglous *et al*, 200; Today's, 2006)



Figure 2.2 - The ultraviolet wavelengths depicted on the electromagnetic spectrum (Today's, 2006)

There are several advantages of UV disinfection for inactivating viruses, spores, and cysts. A low dose of ultraviolet light can kill 99.99 percent of the fecal coliform and fecal streptococcus. UV disinfection is a physical process rather than a chemical; thus, eliminating the need to generate, handle, transport, or store toxic, hazardous, or corrosive chemicals. UV disinfection also produces no toxic residuals that could be harmful to humans or aquatic life. UV disinfection also has the added benefit of breaking down trace organic compounds such as N-methyl-D-asparate (NDMA). (Cheremisinoff, 2002)

There are also several disadvantages to using ultraviolet disinfection. Target organisms can sometimes repair themselves and "undo" the effects of UV disinfection with a phenomenon known as photo-reactivation. The tubes used to carry the water can develop a buildup of biological material that requires periodic cleaning to ensure adequate disinfection. Additionally, it is more difficult to penetrate microorganisms in wastewater that contains high amount of solids in suspension; therefore, it is highly dependent on the efficiency of upstream devices that remove suspended solids. UV disinfection also requires a constant supply of electrical power to ensure proper functionality and UV bulbs can burnout, needing replacement. A further disadvantage of UV is the lack of measurable residuals to indicate the effectiveness of process or to remain in downstream waters to continue preventing microbial growth during transport or storage. (Tchobanoglous *et al*, 2003)



3.0 Design

The final design for the Portable Water Treatment System was chosen after considering four different designs. The final design required an electrical and hydraulic system. The electrical system was modeled using Electronic Workbench's MultiSim 8. The hydraulic design was modeled using hydraulic equations.

After the electrical and hydraulic systems were designed, prototype construction started. The electrical system was completed first while required hydraulic components were being obtained. The electrical system was assembled on a breadboard prior to being soldered on a PCB board. The hydraulic system was assembled on a wooden frame one subsystem at a time. After both systems had preliminary testing completed, the system was installed in a Coleman cooler to simplify transport for non-laboratory testing.

3.1 Design Concepts

PES developed four design concepts that could be implemented to meet the goals and objectives for the system. Schematics of these design concepts are shown in Figure 3.1

- **Design Concept #1** Used a sedimentation tank with flocculating chemicals to settle suspended solids prior to entering system filters and pump. Disinfection would occur by the use of chlorine injection. This design is modeled after a traditional wastewater treatment plant.
- **Design Concept #2** Similar to Design Concept 1 without a settling tank. Disinfection was also changed from chlorine to a UV system to reduce the need for chemicals.
- **Design Concept #3** Built upon Design Concept 2 adding an inline RO membrane.
- **Design Concept #4** Evolved from Design Concept 3. The design added the ability to bypass the RO membrane and recover filtered concentrate water.





Figure 3.1 - Four design concepts for Portable Water Treatment System



3.2 Decision Matrix

The selection of parameters to determine the best treatment system was based on productivity, effectiveness, simplicity, portability, and reliability of the finished system. A rating from 1 to 5 was assigned to each design parameter with 5 possessing the most desirable characteristics. The design alternatives were weighted against all the parameters listed in Table 3.1 to select the best design to meet the goals and objectives.

Parameters	Design 1	Design 2	Design 3	Design 4
Time to treat water	1	4	1	3
Complexity of system	3	3	3	2
Ease of use/operation	2	4	4	5
Size	2	5	4	4
Cost	3	4	3	2
Weight	2	5	4	4
Chemicals required	0	5	5	5
Disinfection realiablity	3	4	4	4
Water quality	3	1	5	5
System realibilty	2	4	4	4
Amount of maintance required	3	3	2	3
Meets goals and objectives	1	1	3	5
Difficulty in construction	2	3	3	2
Total	s 27	46	45	48

Table 3.1- Decision matrix used to choose final design

After comparing the design alternatives, Design Concept #4 with the highest rating of 48 was the chosen for the final design. Design Concept #4 provided high quality treatment of the source water with the ability to change modes to maximize water flowrates when desired. The design also allowed for treatment on a moving platform such as boat. The selected design met the requirement produce safe drinking water under adverse inlet source water conditions. The disadvantage with the chosen design is that it is the most complicated and expensive.

3.3 Patent Search

A patent search was performed in January and February 2006 for similar portable water purification technologies using the online search engine provided by the United States Patent and Trademark Office. The search revealed individual and corporate patents that for systems



that could treat water. The PES Portable Water Treatment System differed from all designs sufficiently to prevent patent infringement; however, some of the individual components have corporate design patents (e.g. the pump and RO membrane). No further action is required by PES to use the patents components since they will be used unaltered. It was also determined that nothing prevented PES from patenting the final design and it may be desirable if work continues on the system. (US Patent and Trademark Office, 2005)

3.4 Hydraulic Design

A schematic of the chosen hydraulic system can be seen in Figure 3.2. The design is composed of several components. Many of components were purchased at major retail home improvement stores (e.g. Home Depot and Ace Hardware) to ensure that replacement parts easily attainable for future repairs.



Figure 3.2 - Hydraulic System Schematic

3.4.1 Reverse Osmosis Design

The RO membrane is one of the most expensive components of the Portable Water Treatment System. RO membranes vary in price, size, flow rates, and operating pressures. As the flow rate of the permeate of the RO filter increases, the price and size goes up substantially. The available RO membranes that would meet the goals and objectives are listed in Table 3.2.



The membrane chosen is best decided by the end-users operational use of the Portable Water Treatment System. For example, if the unit would be primary used to treat seawater, the Dow Corning Filmtec SW-4040 could be installed resulting in increased flow rates under saline conditions. (American RO System, 2006; Dow Corning, 2005; General Electric, 2006)

RO Membrane	Size (diam x length) (inches)	Flow Rate (gal/min)	Pressure (psi)	Price
Filmtec XLE-2521	2.5 x 21	0.25	100	\$109.00
Filmtec XLE-2540	2.5 x 40	0.6	100	\$138.00
Filmtec XLE-4021	4.0 x 21	0.7	100	\$196.00
Filmtec TW30-4040	4.0 x 40	1.7	225	\$223.00
Filmtec SW-4040	4.0 x 40	1.8	225	\$345.00

Table 3.2 - RO Selection

To minimize cost and price of the prototype the Dow Corning Filmtec XLE-2521 RO membrane was purchased. The XLE-2521 was chosen due to a relatively high flow rate, low cost, low-pressure demand, and availability. A photograph of the membrane can be found in Figure 3.3. Vendor supplied technical information for the RO membrane can be found in Appendix A. (Dow Corning, 2005)





Figure 3.3 - Diagram and photograph of RO membrane XLE-2521

The Portable Water Treatment System uses a commercially available RO membrane to allow separation of contaminants from water. The flushing water that contains the rejected contaminants or concentrate water is fed to a recirculation line. The recirculation line connects the concentrate discharge from the RO membrane to the suction of the pump.



Recirculating the concentrate extends the life of the carbon pre-filter and sediment filters by minimizing the amount of raw water that flows through them. The flowrate of concentrate in the recirculation line is controlled by a valve that is adjusted to maintain system backpressure to control the RO process efficiency. The concentrate must be disposed of when total dissolved solids (TDS) levels in the system increase or the RO membrane will not function correctly.

The design allows for the recycle flow line to contain two needles valve so the connection between the dump valve and the inlet line of the system can be closed without out affecting system operation. This second valve is needed to for prevention of backflow from the dump line to the suction of the pump. If the needle valve and solenoid located in the concentrate dump line are fully open, approximately 0.88 gallons per minute will be wasted from the recirculation line.

3.4.2 Filter Design

Four filters are installed in the Portable Water Treatment System to remove suspended particles. The filters go from the largest size pore to the smallest poor size. The first filter is an inlet filter that is designed to remove particles larger than 80-microns to prevent damage to the pump. The inlet filter is easily removed for cleaning in the field. The second filter is a paper sediment filter GE SmartWaterTM FXWPC 20-micron filter used to remove particles greater than 30 microns. The second filter is installed in a clear housing to allow the operator to visually observe when the filter needs replacement. The third filter is a pre carbon block GE SmartWaterTM FXULC 1.0-micron filter used to remove particles greater than 1 micron and organic compounds. The forth filter is an inline 1.0 micron filter used to ensure that any organic material that somehow passed through the rest of the system is removed. The forth filter is located immediately prior to the UV lamp and called the post carbon filter. Additional data on the filters is located in Appendix A. (General Electric, 2006)

3.4.3 Pump

A pump is installed in the system to provide a hydraulic force to allow for flow through the Portable Water Treatment System. The pump was chosen based on maximum pressure



delivery, ability to provide greater than 1.0 gallon per minute flow rate, and size. The pump also needed to be operated on a 12-volts to ensure maximum portability. The SHURflo[®] model #800-443-236 diaphragm pump was chosen. The pump was tested to have a minimum of 6 feet of suction head to lift the water into the pump diaphragm. The pump is rated to produce a flow rate of 1.8 gallons per minute. The inlet pressure on the RO membrane fluctuates between 60 and 80 psi when in AUTO MODE and can be manually adjusted to operate at higher pressure. It is not recommend to set the outlet pressure of the pump higher than 100 psi since the remaining portions of the system are not rated for higher pressures. Vendor supplied technical information for the pump can be found in Appendix A. (SHURflo, 2006)

3.5 Hydraulics Calculations

Various equations and calculations were used to model the system during the hydraulic design of the Portable Water Treatment System. Flow rates, velocities, concentrations, pressures, and production rates were estimated. Appendix B contains flow diagrams used track potential and kinetic energy changes throughout the system.

The calculations were performed under the following assumptions:

- The fluid density remains at a constant density even though substance removal is occurring
- The flow through the system is continuous
- The fluid is incompressible
- Pressure drops determined from testing are accurate

3.5.1 Flow and Velocity Calculations

The entire system must obey the conservation of mass. Equation 3-1 is the continuity equation that is used in determining flow rates. (Hammer and Hammer, 2004)

$$V_1 A_1 = V_2 A_2 = Q \tag{3-1}$$

Where

V = velocity, ft/sA = area of flow, ft²

$$Q =$$
flow rate, ft³/s



In order to keep track of the energy throughout the entire system the extended Bernoulli Equation was used. Equation 3-2 shows the different forms of energy present in the system and how energy can transform as the fluid travels through the system. (Hammer and Hammer, 2004)

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_f - h_p + h_m$$
(3-2)

Where

V = velocity of flow, ft/s $\gamma = \text{specific weight of water, 62.4 lbs/ft}^3$ $g = \text{acceleration due to gravity, 32.2 ft/s}^2$ P = internal pressure, psi z = relative elevation, ft $h_f = \text{head loss due to friction between the fluid and piping, ft}$ $h_p = \text{head produced from the pump, ft}$ $h_m = \text{minor head losses, ft}$

The many fittings throughout the system contribute to head losses that are referred to as minor losses. The minor head losses were calculated using Equation 3.3. Refer to Appendix B for calculations performed to determine minor head losses (Hammer and Hammer, 2004).

$$h_m = Kh_v = K\frac{V^2}{2g} \tag{3-3}$$

Where

 h_m = head loss caused by the various fittings K = loss Coefficient h_V = velocity Head

The values used for K were 0.9 for tees, 0.75 elbow, 0.15 for valves, 2.0 for the check valve, and 7.5 for the flow control valves The minor losses computed were found to be very small and do not contribute greatly to the overall system energy. (Hammer and Hammer, 2004)

The fiction loss through all the pipes was determined using the Darcy-Weisbach equation shown in Equation 3-4. The f factor was determined by finding the Reynolds number with Equation 3-5. (Rorrer, 2001)



$$h_f = f \frac{L}{d} \frac{V_1^2}{2g}$$
(3-4)

Where

 h_f = head loss from friction, ft f = friction factor L = length of pipe, ft V = velocity of flow, ft/s d = diameter of pipe, ft

The friction factor was determined using the Moody chart and relative pipe roughness Equation 3-5 shows how the Reynolds number is computed and the actual calculations are displayed in Appendix B. The flow through the entire system was found to be turbulent, which was suspected, and was performed to find the amount of head losses due to friction. (Rorrer, 2001)

$$Re = \frac{inertial \ forces}{viscous \ forces} = \frac{d\rho V}{\mu}$$
(3-5)

Where

Re = Reynolds number, dimensionless, turbulent flow for Re > 2300 ρ = density of fluid, 62.4 lbs/ft³ V = velocity of flow, ft/s d = diameter of pipe, ft μ = dynamic viscosity, lb/ft·s

The static pressure from the positive displacement pump is about 60 pounds per square inch (psi) which is equivalent to 138 feet of net positive suction head. This is sufficient to provide the required head to the RO membrane.

The flow through the main system should remain constant because of continuity. The law of conservation of mass is obeyed, mass in equals mass out. The fluctuations of energy through the system are achieved with the pressures throughout the system. This flow rate equates to 2.9 feet per second of flow through the system and increases to 6.54 feet per second exiting the system due to a reduction in pipe diameter while bypassing the RO unit.

The selected tubing size has an inside diameter of 3/8-inch for the inlet of the system. The tubing size entering and leaving the RO filter will be 1/4-inch inside diameter tubing. The effluent of clean water from the RO unit is estimated to be about 0.25 gallons per min.



There are two different modes the treatment system can operate which depending on the relative quality of the source water. These two modes are referred to as NORMAL MODE and RO MODE. The flow rates, dissolved solids concentrations, operating pressures, and power use changes within each case. The first case of operation is flow through the main part of the system, bypassing the RO unit. This allows a steady discharge at a minimum rate of 1 gal/min. The second case is switching the path of the water to travel through the RO membrane before it is discharged. Using the RO unit will reduce the flow rate of drinking water from the treatment unit to be reduced by approximately 75%. With approximately 1 gallons per min of flow entering the RO housing, approximately 75% of that flow is dumped, resulting in a low flow rate of drinking water produced by the RO membrane. So much water is dumped to preserve the life of the RO membrane, causing it to flush itself as it produces very high quality water.

3.5.2 Pressure Drop

The pressure drop determined by testing the filter housing and cartridge is approximately 2.5 psi. The housing was tested by running water through it from the faucet having a static pressure of 55 psi. With the water flowing through the filter the incoming pressure was approximately 9 psi and the exit pressure was approximately 6.5 psi. The RO membrane causes a pressure drop of 30 psi and contributes greatly to a loss of energy in the entire system. The inlet pressure of the RO unit is controlled by changing the flow rate of water dumped. The purpose of these calculations is to determine energy throughout the system and where pressures and velocities are maintained to provide the proper flow rate exiting the system.

3.5.3 Total Head Loss

The head loss due to friction, fittings, and filters was added up for both operation in NORMAL MODE and RO MODE. The total head loss found while in NORMAL MODE is approximately 21 feet. The total head loss found while in RO MODE is approximately 87 feet and is much higher because the RO membrane requires such a high inlet pressure for operation. With all the head losses added up there is still sufficient head supplied from the



pump to operate the treatment system without any complications of treating source water effectively. Refer to Appendix B for all head loss calculations performed.

3.6 Electrical Design

The electrical system allows for operation of the three solenoid valves, pump, and UV lamp in the Portable Water Treatment System. The main electrical subsystems are:

- **Control Unit** Allows for user interaction with the system
- Ultraviolet Light Ballast and Transformer Transforms direct current (DC) power from the battery into alternating current (AC) power for the UV light
- **Pump Control System-** Provides for control of system pressure
- **Battery** Supplies main power for all subsystems

3.6.1 Control Unit

The control unit allows for user and automatic control of the system. The control unit is housed in a single plastic enclosure with three plugs that allow for electrical connection with the rest of the system components. Figure 3.4 shows photographs of the inside of the control unit.



Figure 3.4 - Photograph of control unit electronics



The various electrical subsystems are controlled by solid state circuitry. Figure 3.5 is a schematic of electrical components with the separate control sections indicated. Appendix C contains the same electrical schematic with a list of actual electrical components.



Figure 3.5 - Schematic of the Electrical Control Unit with Different Subsections Marked

There are four distinct sections of the control circuitry installed on a PCB board located inside the Control Unit. The four distinct sections indicated on Figure 3.5 are:

- A) **Power and Switching Section** The section supplies a steady variable voltage to the rest of the circuitry. The section also contains all switches to allow user interaction to control the mode of operation.
- **B)** Source Quality Control Section The section monitors the water coming into the system and activates a solenoid if the water resistance is too low. The set point for activating the solenoid can be adjusted depending on desired use.
- **C) Recirculation Quality Control Section** The section monitors the Resistance conductivity and activates a solenoid if the water resistance is too low. The set point for activating the solenoid can be adjusted depending on desired use.



D) Valve Control Section - The section contains the solenoids for operating valves and corresponding indication lights. The power for the solenoids is supplied through one of two relays controlled by the circuitry and mode switch.

The unit contains three switches for user interaction:

- **Main Power Switch** When switched ON the electrical control circuitry is energized and operation of the unit is possible.
- **Pump Control Switch** When switched ON current is supplied to the Pump, UV Ballast and Transformer, and all valve solenoids.
- Mode Selector Switch Three position switch that controls the operation of the electrical control system. When selected to BYPASS MODE the bypass solenoid valve is energized allowing the system to allow water flow to bypass the RO membrane. When selected to AUTO MODE, the conductivity of inlet and recirculation water determines which valve solenoids are activated. When RO MODE is selected, the RO and dump valve solenoids are energized.

The control circuitry contains a three position MODE switch that allows the operator to select one of two manual modes or allow automatic operation. In the RO MODE, all water flows to RO membrane and all concentrate is drained. In the NORMAL MODE, all water flows through the sediment and two carbon filters, bypassing the RO membrane. In the AUTO MODE, the water conductivity is measured at the conductivity cells, located in the inflow and recirculation section of the system, control which valves are open. If the inflow water conductivy is high, indicating high TDS concentration, the bypass valve shuts and the RO valve opens; however, if the inflow water conductivity is low, the bypass valve opens and RO valve shuts maximizing flow though the system. If the recirculation water conductivy is high, indicating high TDS in the Concentrate flow, the dump valve opens; however, if the recirculation water conductivy is high the water is retained to minimize the amount of pretreated water wasted. The control circuitry uses relays that allow separation of the system into high current and low current sections. The relays also prevent electrical noise from affecting conductivity measurements. (Novak, 2003)



The circuitry of the inlet and recirculation control sections is identical, but measure conductivity of system water at two different locations by a probe immersed into the flow stream. As the TDS concentration increases, water is less resistant to electrical current flow. The conductivity probes are connected to two transistors that amplify the current flow through the water via a feedback circuit. At a preset point, controlled by varying the resistance through a potentiometer, the relay will energize allowing or preventing current flow to the valve solenoids. When current is supplied to the valve solenoids the valves will open.

3.6.2 Ultraviolet Light Ballast and Transformer

An electrical system that turns 12 Volts Direct Current (VDC) from the battery into 44 Volts Alternating Current (VAC) is required to run the UV light. The system is composed of two commercially available units. The first unit is an inverter designed to plug into a vehicle 12 VDC utility outlet to power normal 120 VAC household devices. The second unit is a transformer used to convert 120 VAC to 44 VAC. The devices have been modified to fit into a single water resistant enclosure.

3.6.3 Pump Control System

An electrical system controls system hydraulic pressure on the pump by allowing a maximum current to flow to the pump. As the pressure increases in the pump the current it draws is also increased. A pressure switch is built into the housing of the pump that detects outlet pressure of the pump. The pump will turn on or off depending on detected pressure. The pump will energize when the detected pressure is below a controllable set point and turn off when the set point is exceeded. To maintain adequate pressure for the RO unit, the set point for the pump has been set to 100 psi.

3.6.4 Battery

A rechargeable lead-acid battery that is rated at 12 VDC and 35 Amp hours was selected for the system. This sealed battery should supply the system with sufficient power to run at full capacity for seven hours. The battery can be recharged with supplied 120 VAC charger or by plugging into a vehicle 12 VDC utility outlet. The battery purchased is rated for 33 amp-hrs, 12 volts DC, and 33 Joules of stored energy. The battery voltage may drop below 10 volts if



the Portable Water Treatment System is operated for extended periods between recharging. The battery will power the unit when voltage drops below 10 VDC, but should be charged as soon as possible to maintain the life of he battery. Additional data on the battery is located in Appendix A. Refer to Appendix C for battery life calculation and water production resulting from a single charge.

The current required to run all parts with the system in normal operation it was measured to be a maximum 5.5 amps in NORMAL MODE and 6.8 amps while in RO MODE. Providing higher pressures required to effectively utilize the RO membrane requires the pump to draw more energy from the battery. It is suggested to have access solar photovoltaic cells to charge the battery during an extended trip in the wilderness or for emergency situations. For the purpose of testing the prototype system, solar panels were not purchased or configured into the budget but could easily be implemented into the market sales of the portable treatment system.

3.7 Prototype Construction

A prototype was constructed after the design was finalized and all required parts obtained. The prototype was mounted on wooden frame to determine the proper orientation for the various valves, filters, and connection. Photographs of the testing prototype are shown in Figure 3.6.



Figure 3.6 - Photographs of the testing prototype





After verification that all the required components would function together, the system was moved from the bulky testing prototype into a convenient and durable carrying case. A metal-reinforced 20-gallon Coleman cooler was chosen for the carrying case of the final prototype. The cooler was chosen because it was rigid, lightweight, and easy to work with. It also already had a locking lid, drain port, and convenient carrying handles. All components were attached to the inner housing of the cooler using ¹/₄ -inch diameter bolts. Figure 3.7 shows a diagram of how the components are installed in the carrying case. Figure 3.8 and Figure 3.9 show a photographs of the final prototype during testing and after aesthetic improvements.



Figure 3.7 - Orthographic drawing of final prototype





Figure 3.8 - Photograph of the final prototype during testing



Figure 3.9 - Photograph of the final prototype after aesthetic improvements



4.0 Water Analysis

Pure water is a clear, colorless, odorless liquid consisting of two hydrogen atoms and one oxygen atom. Water is the universal solvent capable of dissolving multiple chemicals that are harmful to human health. May of these chemicals cannot be detected by normal senses. Even if impurities are detected by color, odor or taste, without laboratory analysis there is no way to establish the amount of contaminant present. Regular water testing is important to know the true extent of water contamination.

Water quality analysis should always be conducted by a certified laboratory testing facility. Nortest Analytical Laboratories will be contracted to perform objective chemical analysis of indicator standards to test the performance of the Portable Water Treatment System. An outline of the analytical procedures used to determine water quality is given in Appendix D.

4.1 Water Quality Standards

The key indicator in assessing the performance of Portable Water Treatment System is to insure that the Environmental Protection Agency (EPA) national drinking water standards are met regardless of the source water. Any public water supply serving at least 25 or more people must ensure that these standards are met with treatment and regular testing. An abridged list of EPA drinking water standards are shown in Table 4.1. (Environmental Protection Agency, 2006)

Contaminant	Maximum Contaminant Level Goal (MCLG)	Maximum Contaminant Level (MCL)	
Turbidity	N/A	Treatment Technology	
TKN (measured as Nitrogen)	10 mg/L	10 mg/L	
Arsenic	0 mg/L	0.010 mg/L	
Copper	1.3 mg/L	Treatment Technology	
Total Coliforms	Zero	5.0 %	
pН	6.5-8.5	6.5-8.5	
Total Dissolved Solids (TDS)	500 mg/L	500 mg/L	

 Table 4.1 - EPA National Drinking Water Standards (Environmental Protection Agency, 2006)



4.1.1 Total Dissolved Solids

TDS measures the sum of all dissolved material in the water including hardness and alkalinity Monitoring TDS throughout testing procedures will provide a good indication of the overall quality of the water and effectiveness of the system. The concentration of TDS corresponds directly to the conductivity of the water. As the TDS increases, so does conductivity. Portable TDS meters measure the conductivity of the water and relate this value to the TDS present through use of empirically determined conversion factors. Total dissolved solids are measured in parts per million (ppm) or milligrams per liter (mg/L). Fresh water is defined as having less than 1000 mg/L TDS. Brackish water is defined as having TDS content between 1000 and 35,000 mg/L and seawater has TDS content in excess of 35,000 mg/L Tap water in Flagstaff, Arizona exhibits TDS content ranging from 100 to 200 mg/L determined from testing. (LaGrega, 2001)

4.1.2 Conductivity

While pure water is a relatively poor conductor of electricity, natural impurities can transform it into a relatively good conductor. Salts and contaminants in water will separate into ions. These ions constitute impurities in relation to pure water. Electrolytic conductivity is the measure of the ability of a solution to conduct an electric current. Conductivity is a measure of the resistance between two electrically charged probes immersed in a test solution. The conductivity measurement is directly effected by the presence of dissolved ions in solution and will increase with an increased quantity and mobility of ions A high conductivity reading indicates an increase in a solution's ability to conduct electricity. In order to gauge the relative quality of water, the Portable Water Treatment System has conductivity cells measure the conductivity of the inlet water and concentrate in the recirculation line of the unit. (LaGrega, 2001; Novak, 2003)

4.1.3 Turbidity

Turbidity is a quantitative measure of the light transmitting properties of water. Measurement is based on comparison of the intensity of light scattered by a sample to the measure of light scattered by a reference solution under the same conditions. Turbidity is commonly reported



in nephelometric turbidity units (NTU). Turbidity has no related health effects; however, turbidity can be a good indicator of the presence of suspended solids and disease causing bacteria. The EPA surface water treatment rule requires that systems using surface water must filter to meet defined criteria. The EPA mandates that at no time may turbidity exceed 500 NTU. For systems that filter water, turbidity measure may not exceed 1.0 NTU in at least 95% of samples in any given month. (Environmental Protection Agency, 2006)

4.1.4 pH

The pH is the negative logarithm of the hydrogen ion concentration which indicates alkaline or acid content of an aqueous solution. Neutral water has a pH of 7.0. The EPA has set a secondary standard of pH in drinking water between 6.5 and 8.5. These values correlate closely with the pH range required to sustain biological growth. (Environmental Protection Agency, 2006)

4.1.5 Alkalinity

The presence of alkalinity is a measurement of the carbonate and bicarbonate ions of certain elements, most commonly calcium and magnesium. Alkalinity can be used as a measure of the buffering capacity of a solution. The presence of high alkalinity indicates the water will resist change in pH when an acid is introduced. (Hammer and Hammer, 2004)

4.1.6 Hardness

Water that is "hard" is high in dissolved minerals, mainly calcium and magnesium. Water acts as a solvent to dissolve naturally occurring minerals in the environment. If these minerals are present in the soil around a water supply, the level of hardness in the water will indicate this. Hardness in drinking water is not a health threat; however, hard water can cause mineral buildup in plumbing fixtures and can give drinking water a bitter alkali taste. (Hammer and Hammer, 2004)



4.1.7 Nitrogen

Nitrogen in the environment is an essential nutrient for biological growth. Excess nitrogen in drinking water can cause detrimental health effects to certain exposure groups. In infants, excess nitrate (NO_2) intake can cause methemoglobinemia, or blue baby syndrome.(Environmental Protection Agency, 2006)

4.1.8 Organics

The presence of organics in natural water sources can indicate pollution and pesticides. Chemical Oxygen Demand (COD) is a common parameter for measuring organics species. (Environmental Protection Agency, 2006)

4.1.9 Coliform

Coliform bacteria are common in the environment and are usually associated with disease causing germs and bacteria that are the main cause of health effects associated with the drinking of untreated water. One bacterium often associated to total coliform is *Escherichia coli* or *E. Coli*. *E. Coli* can cause severe illness and in some cases may be life threatening. *E. Coli* is normally used to determine the concentration of microorganisms in a water since the species is relatively resistant to disinfection techniques. (LaGrega, 2001)

4.1.10 Metals

The presence of trace metals in surface waters is an important constituent in maintaining biological growth. In excess amounts, metals can inhibit potable uses in these waters because of their inherent toxicity. Heavy metals can also cause damage to the kidneys, liver, and nervous system. It can also cause cancer. High levels of cadmium, mercury and lead in drinking water can cause nerve damage, mental retardation, birth defects and cancer. (Hammer and Hammer, 2004)

4.2 Testing and Sampling

In order to assess the performance of the Portable Water Treatment System, the unit was tested with different sources of surface water. These sources included a perennial river,



standing lake water, and stormwater runoff. All sampling was conducted on Sunday, April 9, 2006.

When possible, analysis was conducted at the sampling site. When required water was collected in clean polyurethane bottles for later analysis in the laboratory. Copper and arsenic are common metals found in Arizona surface waters. These two elements were chosen to be representative metals for performance analysis. Because independent laboratory analysis was conducted for arsenic and copper concentrations, metal analysis was limited to the Verde River site in order to reduce testing costs. Some analysis were beyond the capability of the College of Engineering and Natural Science Environmental laboratory and Nortest Analytical Laboratories was used to perform select water quality analysis. The results of the testing are included in Appendix D and the Chain of Custody Records are included in Appendix E.

4.2.1 Lake Mary

The purpose for sampling at Lake Mary was to use a known municipal source for treatment to gauge system performance against already published drinking water quality reports. Samples from this site were collected at the boat ramp on Upper Lake Mary adjacent to Highway 487. (City of Flagstaff, 2006)

4.2.2 Verde River

Pecks Lake is located in an oxbow on the Verde River near Clarksdale, AZ. Pecks Lake was included on Arizona's 1998 Water Quality Limited Waters List for two stressors, high pH and low dissolved oxygen. The land around Pecks Lake is owned by Phelps Dodge Corporation and contains tailings piles from former mining operations. Due to access problems with Pecks Lake on the date of sampling, we chose to sample at a location on the Verde River adjacent to Pecks Lake in hopes of detecting metals from the source water. The sampling location was located downstream of bridge on Tuzigoot Road on the Verde River.

4.2.3 Sinclair Wash

Sinclair Wash is an ephemeral stream running through the Northern Arizona University campus that collects stormwater runoff from the most of the lower campus of the university.



This wash is an engineered channel with sewer and reclaimed water utilities running directly underneath. The purpose of sampling at this location was to test performance of the system on turbid and standing water that was likely to contain coliform.

4.3 Source water quality

Qualitative screening of source water quality was conducted through the use of Watersafe[®] All-In-One test kits. The kits were used to gauge the relative quality of the source water at the time of sampling. Water quality data for the source water was analyzed in the field and laboratory. The water quality for the source waters are shown in Table 4.2 and Figure 4.1.

Contaminant	Lake Mary	Verde River	Sinclair Wash	
Bacteria	Positive	Positive	Positive	
Lead	Negative	Negative	Inconclusive	
Pesticides	Negative	Negative	Inconclusive	
Copper	Not Sampled	0.02	Not Sampled	
Arsenic	Not Sampled	0.017	Not Sampled	
Sulfate (mg/L)	1	24	2	
рН	7.27	8.45	7.1	
Hardness (mg/L)	36	232	56	
Alkalinity (mg/L)	36	226	42	
Turbidity (NTU)	143	137	996	
TDS (mg/L)	36	260	445	

Table 4.2	-Sample	results	of source	water
1 4010 114	Sumple	I Courto	or source	mater

Note: Red Text indicates out of specification Federal Water Quality Standards



Figure 4.1 - Graph of water quality in source waters


5.0 Results

Results of the final prototype of the Portable Water Treatment System were obtained using a set of standard operating instructions. Operating instructions for the unit are located inside the lid of the unit near the control panel for user convenience and Appendix F. This design manual may also be consulted for more information on system operation.

5.1 Cost and Weight

The number and cost for each part used in the final prototype for the Portable Water Treatment System are listed in Appendix G. The total retail direct cost for the unit was found to be \$745. The final cost was within the allowed budget of \$1000, but \$145 higher than the initially estimated cost of \$600. The increase in cost was due to poor estimating of cost for fittings, adapters, and electrical components. The projected costs for the parts would be \$587 if individual components were purchased wholesale or in bulk.

The Portable Water Treatment System is lightweight enough to be carried by one person. The dry weight of the system without a battery is 28 pounds. When the battery is installed the system weight increases to 55 pounds. With system filled with water, the total weight of the system increases to 80 pounds.

5.2 **Production Rates**

In NORMAL MODE, the flowrate of filtered and disinfected water is approximately 1.4 gallons per minute. Approximately 500 gallons of filtered and disinfected water can be provided on a single battery charge. This flowrate exceeds the design objective of 1.0 gallons per minute; however, the objective of providing 100 gallons of filtered water for 10 days in the wilderness will only be met by charging the unit with a 12 VDC power source or optional solar panel.

In RO MODE, the flowrate of high quality disinfected RO water is 0.08 gallons per minute. The measured flowrate will provide the recommended daily supply of drinking water of 0.5



gallons for 10 people after 1 hour of operation. The unit can provide 23.5 gallons of high quality disinfected RO water on a single battery charge (CNN.com, 2006).

5.3 Water Quality

The treated water from the Portable Water Treatment System was analyzed to determine the effectiveness of the system. To minimize analysis cost and time, testing of all primary drinking water standards was not performed, but sufficient analysis was conducted to obtain trends in removal efficiencies.

5.3.1 Total Dissolved Solids

TDS measurements of the source waters at all three sampling locations were below the EPA drinking water standard of 500 mg/L. Figure 5.1 shows the results of the TDS analysis.



Figure 5.1 - TDS values from source water and different modes of operation

5.3.2 Turbidity

Treatment through the NORMAL MODE did not result in turbidity below required standards set by the EPA of 1 NTU for filtered water; however, the RO MODE reduced turbidity to less than 1 NTU. Figure 5.2 shows the results of the turbidly analysis.





Figure 5.2 - Turbidity values from source water and different modes of operation

5.3.3 Alkalinity & pH

In all cases, the RO MODE was effective at removing alkalinity from the source water, and the NORMAL MODE produced no results in removing alkalinity from the source water. Figure 5.3 shows results from Alkalinity analysis.



Figure 5.3 - Alkalinity values from source water and different modes of operation

The removal of alkalinity impacts the pH level in the treated water. When source water from the Lake Mary site was treated in the RO MODE, the pH level fell below EPA drinking water secondary standards. This effect was attributed to removal of the buffering capacity of natural alkalinity present in the source water. When the alkalinity levels are reduced, treated water lacks the capacity to neutralize acids present in the water. Figure 5.4 shows the results of the pH analysis.





Figure 5.4 - pH values from source water and different modes of operation

5.3.4 Hardness

The sample of source water from the Verde River had the highest concentration of magnesium and calcium resulting in the highest hardness. The high levels potentially correspond to detectable concentration of metallic ions at that location. Figure 5.5 shows the results of the Hardness analysis.



Figure 5.5 - Hardness values from source water and different modes of operation

5.3.5 Chemical Oxygen Demand

An observed reduction in COD levels with NORMAL MODE of operation was not observed. Analysis of COD from RO operations indicated a reduction from all three sample sites. Figure 5.6 shows the results of the COD analysis.





Figure 5.6 - Average COD values from source water and different modes of operation

5.3.6 Select Metals

Figure 5.7 shows results from the copper analysis. There was an increase in copper concentration while in NORMAL MODE which may be due to the presence of copper components in the Portable Water Treatment System or analytical error. Further testing and analysis is recommended to discover the cause of copper in the system. It should be noted that the copper level detected is less than 5 percent of the EPA water quality standard and human health should not be adversely affected. The results from RO MODE indicated a marked decrease in copper concentration.



Figure 5.7 - Copper values from source water and different modes of operation

The EPA MCLG for arsenic in drinking water is set at zero mg/L. Detected arsenic in the source water measured below 0.1 mg/L. The decrease in arsenic concentration from



NORMAL MODE of operation is minimal; however, the RO MODE shows significant arsenic removal.



Figure 5.8 - Arsenic values from source water and different modes of operation

5.3.7 Coliform

Preliminary screening for *E. Coli* through the use of Watersafe[®] All-In-One test kits showed that all three source waters sampled contained coliform bacteria. Due to the limited number of test kits, only water from the NORMAL MODE of operation was tested for *E. Coli* from sampling Upper Lake Mary. There was no *E. Coli* present in the results from Upper Lake Mary using the test kits.

Nortest Analytical Laboratories was contracted to perform an independent analysis for coliform and *E. Coli* from source and treated water from Sinclair Wash. The independent laboratory results showed positive levels of coliform from all three samples and the species *E. Coli* from the NORMAL MODE of operation. The results were unexpected and subject to scrutiny because *E. Coli* was detected in treated water and not source water. The unexpected results could be attributed to the system contributing *E. Coli* or analytical error. After the positive coliform results were obtained, the system was disinfected with a bleach solution and tests re-performed with Watersafe[®] bacteria test kits. Sinclair Wash is an intermittent water source that was dry at the time of the second sampling; therefore, water from Upper Lake Mary was tested on 22 April 2006. The results of the Watersafe[®] bacteria test kits showed the expected results of *E.Coli* in the source water and none in the treated water. It is recommended that further testing for coliform and *E. Coli* be preformed by a secondary



independent laboratory. It is further recommended that parallel samples be taken to detect the likelihood of analytical error.

5.3.8 Overall Reduction

Water analysis shows a substantial difference in analytic concentrations in source and treated water. While water treated through NORMAL MODE indicates removal of turbidity and coliform bacteria only, analytical results from water treated through RO MODE shows significant reduction in all constituents analyzed. Table 5.1 shows percentage reduction for water quality constituents analyzed. In all cases, the maximum percent reduction correlates to the poorest quality source for the constituent analyzed. The results show that if higher concentrations are present higher removal percentage is expected. Summary results for all analysis conducted is given in Appendix D.

	Average NORMAL MODE (%)	Average RO MODE (%)	Maximum Reduction (%)
Alkalinity	NR	88.8	94.1
COD	NR	84.4	90.9
Hardness	NR	92.1	97.4
TDS	NR	94.3	97.1
Copper	NR	50.0	50.0
Arsenic	NR	88.2	88.2
Turbidty	88.6	95.0	99.5
Nitrate	28.9	84.5	90.0
Sulfate	NR	64.0	92.0
E. Coli	ND	ND	ND

Table 5.1 - percentage reduction for each type of analysis

5.4 Problems Encountered

The following is a listing of encountered complications in the development of the Portable Water Treatment System:

• Unanticipated costs: Initial estimates for production costs were exceeded partly due to unanticipated costs. This includes the costs associated with developing the electrical component of the system. Also, individual valves and fittings for the system were purchased at retail and not wholesale value. At a price between 3 and 5 dollars a



piece, the cost associated with the plumbing of the system proved to be more than anticipated.

- **Complexity of electrical system:** The initial designs for the electrical system was too complex to be implemented, but PES successfully adapted the design to develop a reliable and easy to use electrical control system.
- **Estimated Weights:** The project proposal lists a maximum unit weight less than 50 lbs based on similar system's published weights. After the goal was set, it was learned that the published weight did not include a power supply.
- In house laboratory was not yet equipped for all desired analytical testing: Due to a remodeling of the Northern Arizona University Building 69 Environmental Engineering Laboratory, equipment required for certain analysis was unavailable.
- **First RO membrane faulty:** The generic brand RO membrane initially used showed less than 50 percent reduction of TDS. After the faulty membrane was replaced with a brand name membrane, 99 percent reduction for TDS was observed.

5.5 Improvements for Further Development

The following is a listing of recommended improvements for future development of the Portable Water Treatment System:

- **Size/Weight:** There are improvements that could be made to reduce the entire system weight. Smaller filters and solenoids could be used without changing system design. The battery is a major factor in system weight that could be reduced by using more expensive but lighter gel-type battery.
- **Electrical system**: There are improvements that could be made to the electrical system to improve the ease of use the Portable Treatment System. Those improvements include, but are not limited to, self-timers to purge the system, filter change indication lights, conductivity readouts for water quality in the system, and a control system that will stop flow if the UV bulb is not illuminated.



6.0 Conclusion

The PES Portable Water Treatment System meets a need that is not fulfilled in the marketplace by being able to make a wide range of natural and contaminated waters safe for human consumption yet remain portable and relatively inexpensive. The System fills this important need with a relatively high flowrate and ability to remove greater than 90% of tested water quality contaminates. The designed prototype meets and exceeds all original goals and objectives. The system is portable, simple to use, efficient, effective, and relatively inexpensive. Additional time and resources would allow the system to be patented and commercially manufactured. If the Portable Water Treatment System was offered to the public, it may save lives by providing safe drinking water to the masses.



7.0 Bibliography & Works Cited

- American R.O. System. "Filmtec Membranes." February 15, 2006. http://americanro.micronpcweb.com/page2.html
- Happy Partner. *Aqua Partner Purification Unit*. 2006. A Happy Camper. 2006 http://www.ahappycamper.com/products/water_purifiers/partner/ammo.html>.
- Barrrow Company, Inc. *Ultraviolet Disinfection*. 16 October 2005 http://www.barrowcompany.com/systems/sys10.html>.
- Cheremisinoff, Nicolas P. *Handbook of Water and Wastewater Treatment Technologies*. Butterwork-Heinman: MA, 2002.

City of Flagstaff. "Water Quality Report." 2006. 26 January 2006. http://www.flagstaff.az.gov/index.asp?NID=98>.

Coleridge, Samuel Taylor The Rime of the Ancient Mariner. Random House: New York, 2004

- Dime Water Inc. "Desalination Units." 16 October 2005. http://www.dimewater.com/desalination.html>.
- Dow Corning. "Filmtec Products." 15 November 2005. http://www.dow.com/liquidseps/prod/prd_film.htm
- Excel Water Technologies. "Aquamiser Plus Watermaker." 2002. 16 Oct. 2005. http://www.excelwater.com/eng/b2c/detailproduct.php?iID=175&Category=24s>.
- Eisenberg, Talbert N. and E. Joe Middlebrooks. *Reverse Osmosis Treatment of Drinking Water*. Boston: Butterworths, 1986.
- General Electric. "Treating Industrial Water with Membrane Technology" 2005. 27 December 2005 http://www.gewater.com/library/tp/index.jsp.
- Hammer, M.J., Hammer, M. J., Jr. *Water and Wastewater Technology*, 5th ed. Columbus, Ohio. Pearson Prentice Hall, 2004.
- LaGrega, M. Hazardous Waste Management, 2nd ed. New York, NY. McGraw Hill, 2001.
- Manahan, Stanley E. Fundamentals of Environmental Chemistry. CRC Press LLC, 2001
- Masschelein, Willy J. Unit Processes in Drinking Water Treatment. New York: Marcel Dekker, 1992.



- MayoClinic.com. "Water: How Much Should You Drink Every Day?" CNN.com. 2006. http://www.cnn.com/HEALTH/library/NU/00283.html>.
- Noah Water Systems. "The Trekker Portable Series, Water Purification." 2001. Crescendo Associates. 16 Oct. 2005. http://www.noahwater.com/trekker.html.

Novak, Joe. "What is Conductivity and How is it Measured?" Hach, 2003

- Rorrer, G., Welty, J., Wicks, C., Wilson, R. Fundamentals of Momentum, Heat, and Mass Trasfer 4th ed. New York, NY. John Wiley and Sons, Inc., 2001.
- SHURflo. "Product Information." 2 February 2006. http://www.shurflo.com/pages/gen/prod_info.htm
- Tchobanoglous, George, Franklin L. Burton, and H. David Stensel. Wastewater Engineering: Treatment and Reuse 4th Edition. Metcalf & Eddy, Inc. Tata McGraw-Hill Publishing: New York, 2003.
- Today's Healthy Home. "Ultraviolet Water Purifiers." 2006. http://todayshealthyhome.com/water_filters/ultraviolet.htm>.
- United States Environmental Protection Agency. "Current Drinking Water Standards." 6 February 2006. ">http://www.epa.gov/safewater/mcl.html#4>.
- United States Patent and Trademark office. "Patent." 10 November 2006. http://www.uspto.gov/main/patents.htm>

Portable Water Treatment System

Appendix A Component Technical Specification





Filters

One (1) inlet filter One (1) sediment filter with clear housing Model GE SmartWaterTM FXWPC 20-micron filter Recommended replacement every 3 months or 1500 gallons Dry sediment filter weight ~0.4 lbs Wet sediment filter weight ~ 1.2 lbs

One (1) carbon pre filter with filter housing Model GE SmartWaterTM FXULC 1.0-micron filter Recommended replacement every 6 months or 600 gallons Dry carbon filter weight ~0.4 lbs Wet carbon filter weight ~ 1.4 lbs

One (1) inline carbon post filter Recommend replacement every 6 months or 60 gallons Dry inline carbon filter ~ 1.3 lbs

Battery

Ŵerker. WKA12-33J
12V
33 Ah AGM
Sealed and spill proof
Weight ~ 27 lbs

UV Lamp

Flow Rate: 1500 GPD UV output (253.7 nm): 16.7 μ W/cm² Lamp Current: 0.162 A Tube size (O, D): 1/4" Max Pressure: 120 psi Max Temp: 104°F Size: Ø1.9 × 11" Total Weight: 1.1 lbs

Storage case -

Circa 1970s metal cooler with foam insulation Weight ~16.2 lbs

Solenoids

3 RainMaker 12 volt with manual bypass Weight ~ (3 lbs)



Vender Supplied information on XLE-2521 Reverse Osmosis Membrane (Page 1 of 2)

Product Information



FILMTEC Membranes

FILMTEC Extra Low Energy (XLE) Elements for Commercial Systems

Features New FILMTEC[™] XLE elements offer better system performance and economics by operating at very low applied pressure. XLE membrane, made with a patented technology, provides consistent and reliable system performance. And for added convenience, XLE elements are available in a dry state for rapid start-up (see Figure 1 on reverse). The new XLE series of elements replaces TW30LE elements which were made with an older membrane technology.

Product Specifications

		Active Area	Applied Pressure	Permeate Flow Rate	Stabilized Salt	
Product	Part Number	ft ² (m ²)	psig (bar)	gpd (m³/d)	Rejection (%)	
XLE-2521	154530	13 (1.2)	100 (6.9)	365 (1.4)	99.0	
XLE-2540	154543	28 (2.6)	100 (6.9)	850 (3.2)	99.0	_
XLE-4021	154540	36 (3.3)	100 (6.9)	1,025 (3.9)	99.0	
XLE-4040	154546	87 (8 1)	100 (6.9)	2 600 (9 8)	99.0	

1. Permeate flow and salt rejection based on the following test conditions: 500 ppm NaCI feedstream, pressure specified above, 77°F (25°C) and the following recovery rates: XLE-2521, XLE-4021 - 8%; XLE-2540, XLE-4040 - 15%.

2. Permeate flows for individual elements may vary +/-20%

3. For the purpose of improvement, specifications may be updated periodically

Figure 1





cludes two 2-210 EPR ImTec part number ⁹⁰⁰ mber 892

Polyamide Thin-Film Composite

13 psig (0.9 bar)

	Maximum Feed Flow Rate	ate Dimensions – Inches (mm)				
Product	gpm (m ³ /h)	A	В	С	D	
XLE-2521	6 (1.4)	21.0 (533)	1.19 (30.2)	0.75 (19)	2.4 (61)	
XLE-2540	6 (1.4)	40.0 (1,016)	1.19 (30.2)	0.75 (19)	2.4 (61)	
XLE-4021	14 (3.2)	21.0 (533)	1.05 (26.7)	0.75 (19)	3.9 (99)	
XLE-4040	14 (3.2)	40.0 (1,016)	1.05 (26.7)	0.75 (19)	3.9 (99)	
 Refer to FilmTec Design Guidelines for multiple-element systems. 					1 inch = 25.4 mm	

1. Refer to FilmTec Design Guidelines for multiple-element systems. 2. XLE-2521 and XLE-2540 elements fit nominal 2.5-inch I.D. pressure vessel. XLE-4021 and XLE-4040 elements fit nominal 4-inch I.D. pressure vessel.

Operating Limits

- Membrane Type • Maximum Operating Temperature^a
- 113°F (45°C) Maximum Operating Pressure 600 psi (41 bar)
- - Maximum Pressure Drop
 - pH Range, Continuous Operationa 2 - 11
- pH Range, Short-Term Cleaning^b 1 – 12
- Maximum Feed Silt Density Index SDI 5
- Free Chlorine Tolerance^c
- <0.1 ppm Maximum temperature for continuous operation above pH 10 is 95°F (35°C).
 - Refer to Cleaning Guidelines in specification sheet 609-23010.

Under certain conditions, the presence of free chlorine and other oxidizing agents will cause premature membrane failure. Since oxidation damage is not covered under warranty, FilmTec recommends removing residual free chlorine by pretreatment prior to membrane exposure. Please refer to technical bulletin 609-22010 for more information.



Vender Supplied information on XLE-2521 Reverse Osmosis Membrane (Page 2 of 2)







Vender Supplied information on SHURflo[®] 800-443-236 Pump (Page 1 of 2)





Vender Supplied information on SHURflo[©] 800-443-236 Pump (Page 2 of 2)



5000 KAIELLA AVEAUE, CYPRESS CA. 90030 (502) /95-5200 (300) 554-5218 FAA (502) /95-7554 SHURio EAST, 52748 PARK SIX COURT, ELKHART, IN 46514 (574) 262-0478 (800) 762-8094 FAX (574) 262-0478 SHURio LIMITED, UNIT 5, STERLING PARK 44 (0) 1293-424-000 FAX 44 (0) 1293-421-880

Portable Water Treatment System

Appendix B Hydraulic Data





Figure B1 shows the flow path while in NORMAL MODE. The inlet was placed six feet below the inlet of the pump and the flow rate was set at approximately 1 gal/min to find the minimum pump head required to produce such a flow rate. The total system energy from inlet to outlet while in NORMAL MODE was equated as follows:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_f - h_p + h_m$$
$$0 + \frac{(2.9 ft/s)^2}{2(32.2 ft/s^2)} + 0 = 0 + \frac{(6.54 ft/s)^2}{2(32.2 ft/s^2)} + 6 ft + 21 ft - h_p$$

 $\Rightarrow h_p = 27.5 ft \text{ min } required \text{ for NORMAL MODE}$



Figure B1 - Main system flow (NORMAL MODE)



Figure B2 shows the flow path while in RO MODE. The energy was analyzed from the inlet at 6 ft below the pump inlet to the exit of the RO unit. The flow path is routed in two directions exiting the RO unit, into the UV lamp and to the dump line. The velocities exiting the RO unit were combined and entered into the energy equation to determine the minimum head required from the pump to produce the desired flow rates. The energy equation for RO MODE is as follows:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_f - h_p + h_m$$
$$0 + \frac{(2.9 \text{ ft}/\text{s})^2}{64.4 \text{ ft}/\text{s}^2} + 0 = 0 + \frac{(6.52 \text{ ft}/\text{s})^2}{64.4 \text{ ft}.\text{s}^2} + 6 \text{ ft} + 87 - h_p$$

 $\Rightarrow h_p = 93.5 ft \text{ min } required \text{ for RO MODE}$



Figure B2 - RO system flow disinfection (RO MODE)



Maximum head from pump:

$$60 \frac{lb}{in^2} \left(\frac{144in^2}{1ft^2}\right) \left(\frac{1}{62.4lb/ft^3}\right) = 138 ft \max pump head$$

Flow velocity from pump:

Flow velocity exiting RO system with 1/4" tubing:

$$A = \frac{\pi (1/4in.)^2}{4} = 0.049in.^2 \left(\frac{1ft^2}{144in.^2}\right) = 3.41x10^{-4} ft^2$$
$$Q = 0.125 \frac{gal}{\min} \left(\frac{1\min}{60s}\right) \left(\frac{1ft^3}{7.48gal}\right) = 2.79x10^{-4} \frac{ft^3}{s}$$
$$V = \frac{0.000279 \frac{ft^3}{s}}{0.000341 ft^2} = 0.082 ft s$$

Flow exit velocity while in NORMAL MODE:

$$Q = 1.0 \frac{gal}{\min} \left(\frac{1\min}{60s} \right) \left(\frac{1ft^3}{7.48gal} \right) = 2.23x10^{-3} \frac{ft^3}{s}$$
$$V = \frac{0.00223 \frac{ft^3}{s}}{0.000341 ft^2} = 6.54 \frac{ft}{s}$$

Reynolds number for 3/8" and 1/4" tubing:

$$\operatorname{Re} = \frac{inertial\ forces}{viscous\ forces} = \frac{d\rho V}{\mu} = \frac{4\rho Q}{\pi\mu d} = \frac{4*62.4lb / ft^3 * 0.00223 ft^3 / s}{3.1459 * 0.000669lb / ft \cdot s * 0.03125 ft} = 8226$$

$$\operatorname{Re} = \frac{4*62.4lb / ft^3 * 0.00223 ft^3 / s}{3.1459*0.000669lb / ft \cdot s * 0.021 ft} = 12611$$



Head loss due to friction:

 $\frac{\varepsilon}{d} = \frac{pipe \ roughness}{pipe \ diameter} = \frac{0.000005}{0.375in.} = 0.000013 \ for \ a \ smooth \ pipe$ $\Rightarrow f = 0.008 \ for \ 3/8" \ tubing \ and \ 0.007 \ for \ 1/4" \ tubing$ $h_f = f \ \frac{L}{d} \frac{V_1^2}{2g} = 0.008 \frac{10 \ ft}{0.03125 \ ft} \frac{(2.9 \ ft/s)^2}{2(32.2 \ ft/s^2)} = 0.334 \ ft$ $h_f = 0.007 \ \frac{8 \ ft}{0.021 \ ft} \frac{(6.54 \ ft/s)^2}{2(32.2 \ ft/s^2)} = 1.77 \ ft$

Minor losses due to fittings and valves for NORMAL MODE:

$$h_{m} = 0.9 \frac{(2.9 ft/s)^{2}}{2(32.2 ft/s^{2})} = 0.12 X 5 tees = 0.60 ft$$

$$h_{m} = 0.9 \frac{(6.54 ft/s)^{2}}{2(32.2 ft/s^{2})} = 0.60 ft$$

$$h_{m} = 0.75 \frac{(2.9 ft/s)^{2}}{2(32.2 ft/s^{2})} = 0.098 X 4 = 0.40 ft$$

$$h_{m} = 0.15 \frac{(2.9 ft/s)^{2}}{2(32.2 ft/s^{2})} = 0.02 ft$$
Total minor head loss = **1.62 ft**

Minor losses due to fittings and valves for RO MODE:

$$h_m = 2.0 \frac{(0.82 ft/s)^2}{64.2 ft/s^2} = 0.021 ft$$

$$h_m = 0.9 \frac{(0.82 ft/s)^2}{64.4 ft/s^2} = 0.009 X 2 = 0.018 ft$$

Total minor head loss = **1.10 ft**

Head loss due to pressure drops caused by filter cartridges:

There are a total of three filter cartridges that are estimated to cause 2.5 psi decrease determined through testing. The RO membrane itself causes 30 psi decrease from inlet to outlet.

$$3 X 2.5 psi = 7.5 psi \left(\frac{144 in.^{2}}{1 ft^{2}}\right) \left(\frac{1}{62.4 lbs / ft^{3}}\right) = 17.3 ft$$
$$30 psi \left(\frac{144}{1}\right) \left(\frac{1}{62.4}\right) = 69.2 ft$$

Total head losses:

NORMAL MODE = **21 feet** ROMODE = **87 feet**

Portable Water Treatment System

Appendix C Electrical System





Figure C1 - Electrical Circuit Logic Flowchart





Figure C2 - Electronic schematic



Quantity	Description	Schematic Label
1	CAPACITOR, 4.7uF	C1
1	DIODE, 1N4001GP	D7
1	LED, LED orange	LED3
1	LED, LED red	LED7
1	POTENTIOMETER, 10K LIN	R3
1	RESISTOR, 1000hm 5%	R10
1	RESISTOR, 10kOhm 5%	R4
1	SWITCH, ONE POSISTION	J1
1	SWITCH, THREE POSISTION	S5
1	VARIABLE VOLTAGE REG LM317T	U4
2	BJT NPN, TIP31	Q3, Q1
2	BJT PNP, TIP42	Q4, Q2
2	LED, LED green	LED4, LED1
2	POTENTIOMETER, 1M LIN	R13, R7
2	RESISTOR, 3900hm 5%	R14, R9
4	CONNECTORS, TEST PTS	J5, J4, J3, J2
4	RESISTOR, 1.0kOhm 5%	R2, R18, R11, R1
5	DIODE, 1N914	D2, D3, D5, D6, D1

Table C1 - Component list for electronic schematic

Calculated runtime in NORMAL MODE

$$\frac{33amp - hrs}{5.5 amps} = 6.0 hrs of battery life$$
$$1\frac{gal}{min} \left(\frac{60 min}{1hr}\right) (6.0hr) = 360 gal$$

Calculated runtime in RO MODE

$$\frac{33amp - hrs}{6.8 amps} = 4.9 hrs of battery life$$
$$0.08 \frac{gal}{min} \left(\frac{60 \min}{1hr}\right) (4.9hr) = 23.5 gal$$

Portable Water Treatment System

Appendix D Analytical Procedures and Results





Table D1 - Chemical Analysis Performed

Analyte	Method	Summary	Equipment	Reagents Used	
		General Wat	ter Chemistry		
Color	Color Direct Observation				
Conductivity	Equipment Manual	Specific conductance	Conductivity cell	Calibration Standards	
Total Dissolved Solids	Equipment Manual	TDS Meter	TDS Meter	Calibration Standards	
Turbidity	EPA 180.1	Nephelometry	Turbidimeter, nephelometer	Calibration Standards- Fomazin recommended. For verification uses: • Hydrazine sulfate • hexamethyleneetetramine	
рН	Equipment Manual	рН	pH meter	Calibration Standards	
		Inorgani	c Material		
Alkalinity Hardness	HACH 8221 HACH 8226	Buret Titration Buret Titration		 Phenolphthalein indicator powder pillow Sulfuric acid standard solution, 0.020 N Bromcrestol green- methyl red indicator powder pillow Magnesium standard solution Potassium Hydroxide standard solution Calcium indicator powder pillow TitraVer Hardness Titrant 	
		Organic	Material		
COD	HACH 8231	Dichromate Reactor Digester / Buret Titration	COD reactor	 COD Digestion Reagent Vial Ferroin Indicator Solutions Ferrous Ammonium Sulfate Standard Solutions Sulfuric Acid 	
		Biol	ogical		
E. Coli	 Independer 	nt Lab Analysis			
Representative Metals					
Arsenic	Independer	nt Lab Analysis			
Copper	Independent Lab Analysis				



 Table D2 - Detail on Total Dissolved Solids Analysis

	Total Solids
Method	TDS Meter
Commence	Conductivity bench meter uses a conversion factor $(0.4 - 1.0)$ to
Summary	convert from conductivity measurements to TDS readings.
Sample Handling	200 mL plastic container
Drasaryation	Analyze as soon as possible, refrigerate to 4°C or below to reduce
rieservation	microbiological decomposition of solids
Max. Hold Time	7 days
Reagents	Calibration Standard: 774.7 ppm
Calibration	Select a calibration solution that is approximately 2/3 of the full scale
Calibration	value of the intended measurement range. Use one point per range
Conversion Factor	Factor = Actual TDS + Actual Conductivity @ 25°C
Detection Limit	300 to 850 ppm

Table D3 - Detail on Conductivity Analysis

Conductivity		
Method	Conductivity cell	
Summary	contact sensor	
Sample Handling	Collect at least 500 mL sample in polyethylene or glass bottle	
Preservation	Refrigerate	
Hold Time	28 days	
Reagents	Calibration Standard: 1413 µS	
Calibration	Select a calibration solution that is approximately 2/3 of the full scale	
	value of the intended measurement range. Use one point per range	
Detection Limit	0 to 1999 μS	

Table D4 - Detail on Total Coliform Analysis

Total Coliform		
Method	SM 9223 B	
Summary	Enzyme Substrate	
Sample Handling	125 mL sterile plastic	
Preservation	Refrigerate at 1 to 4°C	
Max. Hold Time	6 hour hold time recommended, 24 hour max.	
Reagents	N/A	



Table D5 - Detail on Turbidity Analysis

Turbidity		
Method	EPA 180.1	
Summary	Nephelometry	
Sample Handling	No preservation is needed, collect sample in plastic or glass container. Analyze samples as soon as possible	
Preservation	Chemical preservation is not required. If needed, maintain samples at 4°C or below	
Max. Hold Time	48 hours	
Reagents	Calibration Standards- Fomazin recommended. For verification method uses: Hydrazine sulfate, Hexamethyleneetetramine	
Detection Limit	See equipment manual	

Table D6 - Detail on Conductivity Analysis

pH		
Method	EPA 150.1	
Summary	use pH meter, electrometric measurement	
Sample Handling	Collect sample in plastic or glass container. Analyze within 2 hours.	
Preservation	No preservation is required.	
Max. Hold Time	1 day	
Reagents	Calibration Standards: NIST	
	De-ionized water	
Calibration	Use standard calibration buffers to perform at least 2-point calibration	
	that brackets the expected pH range	
Detection Limit	-2.00 to 16.00 pH	

Table D7 - Detail on Alkalinity Analysis

	Alkalinity
Method	SM 2320 B/ HACH 8221
Summary	Buret Titration
Sample	glass or plastic bottles, fill completely and cap tightly. Analyze samples
Handling	as soon as possible.
Preservation	Samples can be stored at least 24 hours by cooling to 4°C or below,
	warm to room temperature before analyzing.
	 Phenolphthalein indicator powder pillow
Reagents	 Sulfuric acid standard solution, 0.020 N
	 Bromcrestol green-methyl red indicator powder pillow
Detection Limit	



	Total Hardness			
Method	HACH 8221			
Summary	Buret Titration			
Sample Handling	Prepare sample containers in plastic or glass bottles washed with detergent and 1:1 Nitric Acid Solution (Cat. No. 2540-49). Analyze promptly.			
Preservation	add 1.5 mL Nitric Acid (Cat. No. 152-49) per liter of sample. Acidify to a $pH < 2$ for a storage of at least 6 months at room temperature. Before analysis, adjust sample to pH 7 and adjust for volume.			
Reagents	 Magnesium standard solution Potassium Hydroxide standard solution Calcium indicator powder pillow TitraVer Hardness Titrant 			
Detection Limit				

Table D8 - Detail on Total Hardness Analysis

<http://www.hach.com/fmmimghach?/CODE%3AHARDNESSCA_BT_OTHER_1860%7C1>

Table D9 - Detail on Chemical Oxygen Demand Analysis

	COD
Method	HACH 8231
Summary	Dichromate Reactor Digestion
Sample Handling	Sample in glass bottles preferably, homogenize samples containing solids, test biologically active samples as soon as possible.
Preservation	acidify sample with sulfuric acid (Cat. No. 979-49) to a pH $<$ 2, keep refrigerated at 4°C, store for up to 28 days.
Reagents	
Detection Limit	0 to 1500 mg/L COD
1 // 1 1 //	1 1 10/CODEN/ AL OVINCENICOD DE OFFIED D10100/ FC1

 $< http://www.hach.com/fmmimghach?/CODE\%3AOXYGENCOD_BT_OTHER_R1810\%7C1>$

Table D10 - Detail on Metals Analysis

	Metals
Method	EPA 200.7
Summary	Inductively Coupled Plasma – Atomic Emission Spectrometry
Sample Handling	Sample containers provided by certified laboratory
Preservation	Acid preservation, not required if delivered to the lab within two
	weeks
Max. Hold Time	6 months if acid preserved
Reagents	N/A



Results for metal analysis from Nortest Analytical Laboratories

Nortest Analytical		Proje	ect: Drir	king Water A	nalysis			
2400 E. Huntington Dr.	Proje	Project Number: PES (560172 - 560177) Reported:						
Flagstaff, AZ 86004	Projec	ct Manag		04/18/	/06 10:15			
ecks -S-01 (Verde River) (604	0506-01) Water (0	Grab)	Samp	led: 04/09/06	6 13:55 Re	eceived: 0	4/11/06 14	:00
Analita	Baguit		Linite	Dilution Dotob	Dramanad	Analyzed	b d a tha a d	Nister
Analyte	Result	RL	Units	DilutionBatch	Prepared	Analyzed	Wethod	Notes
otal Metals								
rsenic .	0.017	0.002	mg/L	1 B6D02	58 04/11/06 16:00	04/12/06 08:20	EPA 200.9	
ecks -N-01 (Verde River) (604	10506-02) Drinking	Water	(Grab) Sampled	: 04/09/06	14:20 Re	ceived: 04	/11/06 14:0
	-			9.11		,		
Analyte	Result	RL	Units	Dilution Batch	Prepared	Analyzed	Method	Notes
antest strategy of the				<i>\$</i> 2				
otal Metals						-		_
rsenic	0.015	0.002	mg/L	1 B6D02	58 04/11/06 16:00	04/12/06 08:20	EPA 200.9	
/ecks -RO-01 (Verde River) (60 4.00	040506-03) Drinkir	ig Wate	er (Gra	b) Sample	ed: 04/09/06	613:55 F	Received: (04/11/06
4.00								
Analyte	Result	RL	Units	DilutionBatch	Prepared	Analyzed	Method	Notes
otal Metals								
rsenic	<0.002	0.002	ma/l	1 B6D02	58 04/11/06 16:00	04/12/06 08:20	EPA 200 9	
ecks-S-02 (Verde River) (604)	0506-04) Water (G	irah)	Sample	ed: 04/09/06	13.55 Re	ceived: 0/	1/11/06 14:	00
		nub)	bampi	-u. 04/00/00	10.00 110	cerveu. v-		
Analyte	Result	RL	Units	Dilution Batch	Prepared	Analyzed	Method	Notes
otal Metals								
opper	0.02	0.01	mg/L	1 B6D02	57 04/11/06 16:00	04/13/06 17:12	EPA 200.7	
ecks-N-02 (Verde River) (604	0506-05) Drinking	Water	(Grab)	Sampled:	: 04/09/06 1	4:20 Red	ceived: 04/	/11/06 14:0
Analyte	Result	RL	Units	DilutionBatch	Prepared	Analyzed	Method	Notes
otal Motals								
opper	0.06	0.01	ma/l	1 860024	57 04/44/05 45:00	04/42/06 47.45	EDA 200 7	
ecks-RO-02 (Verde River) (60	40506-06) Drinkin	a Wate	r (Gra	a) Sample	d: 04/09/06	12.55 D	acoived: 0	1/11/06
4:00	40000-007 Brinkin	y wate	(Ora	of Sample	u. 04/03/00	13.33 10	eceiveu, v	4/11/00
Analyte	Result	RL	Units	Dilution Batch	Prepared	Analyzed	Method	Notes
							mound	
otal Metals								
opper	0.01	0.01	mg/L	1 B6D025	57 04/11/06 16:00	04/13/06 17:18	EPA 200.7	

Legend Technical Services of Arizona, Inc. Certifications: AZ #0004 MN #004--999-387 AIHA #102982 The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.



Results from Nortest Analytical Laboratories for Sinclair Wash source water

		DRINKING WA SAMPLES	TO BE TAK PUBLIC BE FILLED	ROF ENVIRON ROBIOLOGICAI EN IN DISTRIBUTIO WATER INFORMA DUT BY SYSTEM F	NIMENTAL QUAI L ANALYSIS RE ON SYSTEM ONLY TION PERSONNEL	PORT	
		SY	STEM I	FORMATIO	N	AUTHORIZED S	SIGNATURE
SYSTEM	A ID. NO.			SYST	EM NAME		
					C. XMAC	영영 : 2011년 1월 19	
SAMPL	E DATE	SAMPLE TIME		Call	MAILING ADD	RESS	
04,09	106	17:45	ILLA	Paseo de	Bio		
		>		•	OWNER / CONTAC	T PERSON	
			Mar	k Abrah	ams		
OWN	ER / CONTACT PE	RSON FAX NO.		OWNER / CONTAG	CT PERSON TELEP	HONE NO.	
			1814) 243-5	5933		
	COMPLIANC				USE IF INITIAL	SAMPLE WAS POSITI	CIMEN NO
SAMPLE (COLLECTION POIN	T/ IDENTIFICATION			REDEA		NI NI
	ZONE				REDE		
S	AMPLE COLLECT	ION POINT / IDENTIFIC	CATION		DEDECT		
Sinclair	Wash SV	N-5-01			REPEAT,	DOWNSTREAM LOCA	HON
REC	EIVED DATE / TIM	1E			REPEA	T, UPSTREAM LOCATI	ON
4.10.	h/	25				30,	
ANAYLIS METHOD	MCL VALUE	CONTAMINANT N	IAME	CONTAMINANT CODE	TEST START DATE / TIME	TEST COMPLETE DATE / TIME	RESULT
309	PRESENT / 1 1 OR MORE COLIFORM	TOTAL COLIFO	RM	3000	4.10.06	4.11.05	1
		ONLY REPOR	RT FECAL R	ESULT IF TOTAL F	RESULT IS POSITIV	Έ	
ANAYLIS METHOD	MCL VALUE	CONTAMINANT N	IAME	CONTAMINANT CODE	TEST START DATE / TIME	TEST COMPLETE DATE / TIME	RESULT
309	PRESENT / 1 1 OR MORE COLIFORM	E COLI		3013		4.11.06	0
	SPECIMEN NO.			L			
G	1891						
			ROPAT		ATION		
		то ве	FILLED OUT	BY LABORATOR	YPERSONNAL		
LAB I	D. NO.			LABORA	TORY NAME		
AZC)420	Nortest Ana	lytical 24	00 E Huntingtor	n Drive · Flagstaf	f, AZ 86004 · (928)	774-2312
				COMMENTS			
	~				4		
	AUTHORIZ	ED SIGNATURE					
A	at	1					
DATE	PUBLIC WATER S	YSTEM / PERSON NO	TIFIED			78	
01.11	Mark. BI	4)-243-5930	3 (CH) 41	.06	TEMP =	0°C	
Call ed	0						



Results from Nortest Analytical Laboratories for Sinclair Wash NORMAL MODE treated water

		то	BE FILLED (OUT BY SYSTEM P	ERSONNEL		
		SY	STEM IN	FORMATION	N	AUTHORIZED S	
SYSTEM	ID. NO.			SYST	EM NAME		
							-
SAMPL	E DATE	SAMPLE TIME			MAILING ADD	RESS	
04 109	106	18:05	114	A Paseo	del Ric		
		1			OWNER / CONTAC	T PERSON	
			Mai	rk Abra	hans		
OWNER / CONTACT PERSON FAX NO.				OWNER / CONTAC	T PERSON TELEP	HONE NO.	
			(81	4) 243 0	5933		
	SAMPLE T	YPE CE MONITORING			USE IF INITIAL	SAMPLE WAS POSITI BINAL VIOLATING SPE	VE CIMEN NO.
SAMPLE C	COLLECTION PO	NT/ IDENTIFICATION			REPEA	T, ORIGINAL LOCATIO	DN
	ZONE		the second second		REPE	AT, OTHER LOCATION	٨
S	AMPLE COLLEC	FION POINT / IDENTIFI	CATION		REPEAT,	DOWNSTREAM LOCA	TION
Sinclair	Wash/SM	I-P-0155	~		REPEAT, UPSTREAM LOCATION		
ANAYLIS METHOD 309	MCL VALUE PRESENT / 1 1 OR MORE	CONTAMINANT N TOTAL COLIFC		CONTAMINANT CODE 3000	TEST START DATE / TIME	TEST COMPLETE DATE / TIME	RESULT
	COLIFORM				1120	1515	1
		ONLY REPO	RT FECAL R	ESULT IF TOTAL F	RESULT IS POSITIV	E	
METHOD	MCL VALUE	CONTAMINANT	NAME	CODE	DATE / TIME	DATE / TIME	RESULT
	PRESENT / 1 1 OR MORE COLIFORM	E COLI		3013	- 593}	4.11.06 1515	
309							
309	SPECIMEN NO.						
309	SPECIMEN NO.	LA					
309	ISQZ	LA то ве	BORAT	ORY INFORM	MATION Y PERSONNAL TORY NAME		
309	SPECIMEN NO. 1 5 9 2 ID. NO. 0420	LA TO BE Nortest Ana	ABORAT FILLED OUT	ORY INFORM BY LABORATORY LABORA 400 E Huntingtor	IATION Y PERSONNAL TORY NAME	f, AZ 86004 · (928)	774-2312
309 LAB I AZ	SPECIMEN NO. 1 S q 10. NO. 0420	LA TO BE Nortest Ana	ABORAT FILLED OUT	ORY INFORM T BY LABORATOR LABORA 400 E Huntingtor COMMENTS	MATION Y PERSONNAL TORY NAME D Drive - Flagstaf	f, AZ 86004 · (928)	774-2312
309	SPECIMEN NO. SQ ID. NO. 0420	LA TO BE Nortest Ana	ABORAT FILLED OUT	ORY INFORM TBY LABORATOR LABORA 400 E Huntingtor COMMENTS	Y PERSONNAL TORY NAME D Drive · Flagstaf	f, AZ 86004 · (928)	774-2312
309	SPECIMEN NO. ISQ	LA TO BE Nortest Ana ZED SIGNATURE	ABORAT FILLED OUT	ORY INFORM TBY LABORATOR LABORA 400 E Huntingtor COMMENTS	PERSONNAL TORY NAME Drive · Flagstaf	f, AZ 86004 · (928)	774-2312
309 LAB AZU	SPECIMEN NO. SQ ID. NO. 0420	LA TO BE Nortest Ana ZED SIGNATURE	ABORAT FILLED OUT	ORY INFORM T BY LABORATORY LABORA 400 E Huntingtor COMMENTS	PERSONNAL TORY NAME Drive · Flagstaf	f, AZ 86004 · (928)	774-2312



Results from Nortest Analytical Laboratories for Sinclair Wash RO MODE treated water

		SAMPLES	TO BE TAK PUBLIC BE FILLED (EN IN DISTRIBUTIO WATER INFORMAT OUT BY SYSTEM P	ON SYSTEM ONLY FION ERSONNEL				
		SY	STEM		N	AUTHORIZED S			
SYSTEM	ID. NO.			SYST	EM NAME	RELEASE REFO	KT TO ADEC		
SAMPL	E DATE	SAMPLE TIME	MAILING ADDRESS						
04 109	06	18:05	114	A Paseo	del Ric	>			
	- Sec	1 4		<u>,</u>	OWNER / CONTAC	T PERSON			
			Ma	rk Abra	hans				
OWN	ER / CONTACT F	PERSON FAX NO.		OWNER / CONTAC	CT PERSON TELEP	HONE NO.			
			181	147 243 0	5933				
	SAMPLE				USE IF INITIAL	SAMPLE WAS POSITI GINAL VIOLATING SPE	IVE ECIMEN NO.		
SAMPLE C	COLLECTION PO	INT/ IDENTIFICATION			REPEA	T, ORIGINAL LOCATIO	NC		
	ZONE			2.1	REPE	AT, OTHER LOCATION	N		
S	AMPLE COLLEC	TION POINT / IDENTIFIC	CATION		REPEAT, DOWNSTREAM LOCATION				
Sinclair	Wash/SM	U-N-0155	5		REPEAT, UPSTREAM LOCATION				
METHOD 309	MCL VALUE PRESENT / 1 1 OR MORE	CONTAMINANT NAME TOTAL COLIFORM		CODE 3000	UATE / TIME	4.11.06	RESULT		
	COLIFORINI	ONLY REPO	RT FECAL F	ESULT IF TOTAL F	RESULT IS POSITIV	1515 E			
ANAYLIS METHOD	MCL VALUE	CONTAMINANT N	IAME	CONTAMINANT CODE	TEST START DATE / TIME	TEST COMPLETE DATE / TIME	RESULT		
309	PRESENT / 1 1 OR MORE COLIFORM	E COLI		3013	- 5933	4.11.06 1515			
1	SPECIMEN NO.								
6	1292								
		LA TO BE	BORAT	ORY INFORM	VIATION Y PERSONNAL				
I AR I	D. NO.	Nortest Ana	lytical 2	LABORA	Drive - Flagetat	f A7 86004 . (028)	774-2312		
Δ7		Noncest And	Tytical 2		T Drive Tragstar	1, AZ 00004 (920)	114-2012		
AZ				COMMENTS	6				
AZ		ZED SIGNATURE		1					
AZ	AUTHOR			1					
AZ	AUTHOR	2							
AZ	AUTHOR PUBLIC WATER	SYSTEM / PERSON NO	TIFIED]		0.0			


ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY DRINKING WATER MICROBIOLOGICAL ANALYSIS REPORT SAMPLES TO BE TAKEN IN DISTRIBUTION SYSTEM ONLY PUBLIC WATER INFORMATION TO BE FILLED OUT BY SYSTEM PERSONNEL AUTHORIZED SIGNATURE SYSTEM INFORMATION RELEASE REPORT TO ADEQ SYSTEM ID. NO. SYSTEM NAME SAMPLE DATE SAMPLE TIME MAILING ADDRESS 45 114A Paseo Rio 00 106 17: de OWNER / CONTACT PERSON Mark Abrah mS OWNER / CONTACT PERSON FAX NO. OWNER / CONTACT PERSON TELEPHONE NO. 814 243-5 22 SAMPLE TYPE USE IF INITIAL SAMPLE WAS POSITIVE COMPLIANCE MONITORING ORIGINAL VIOLATING SPECIMEN NO. SAMPLE COLLECTION POINT/ IDENTIFICATION REPEAT, ORIGINAL LOCATION ZONE REPEAT, OTHER LOCATION SAMPLE COLLECTION POINT / IDENTIFICATION REPEAT, DOWNSTREAM LOCATION SIN-ROla:r Wash REPEAT, UPSTREAM LOCATION RECEIVED DATE / TIME 4.10.0 035 MICROBIOLOGICAL ANAYLSIS TO BE FILLED OUT BY LABORATORY PERSONNAL ANAYLIS CONTAMINANT TEST COMPLETE TEST START MCL VALUE CONTAMINANT NAME RESULT METHOD CODE DATE / TIME DATE / TIME PRESENT / 1 4.10.06 4.11.06 1 OR MORE TOTAL COLIFORM 309 3000 COLIFORM 1515 20 ONLY REPORT FECAL RESULT IF TOTAL RESULT IS POSITIVE ANAYLIS CONTAMINANT TEST START TEST COMPLETE MCL VALUE CONTAMINANT NAME **RESULT** METHOD CODE DATE / TIME DATE / TIME PRESENT / 1 4.11.06. 1 OR MORE E COLI 309 3013 O COLIFORM ISIC SPECIMEN NO LABORATORY INFORMATION TO BE FILLED OUT BY LABORATORY PERSONNAL LAB ID. NO. LABORATORY NAME AZ0420 Nortest Analytical 2400 E Huntington Drive · Flagstaff, AZ 86004 · (928) 774-2312 COMMENTS AUTHORIZED SIGNATURE DATE PUBLIC WATER SYSTEM / PERSON NOTIFIED TEMP = 8 4 °C Mark. (X14)-Z43-5933 (CH. UILO 748©96 WTI White - Laboratory; Yellow - Client; Pink - ADEQ 091096 DWAR 1: REV. 2/1/05



	Sample Time	Temp (°C)	COD (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	рН	TDS (mg/L)	E. Coli (pos/neg)	Copper (mg/L)	Arsenic (mg/L)	Turbidity (NTU)	Nitrate (mg/L)	Sulfate (mg/L)	
UPPER LAKE MARY														
Source	9:50	12	40	36	36	7.27	30.8	Pos			143	0.2	1	
Normal	9:55	12	27	34	36	6.80	36.1				20.4	0.2	2	
Reverse Osmosis	10:05	13	9	2	4	5.80	3.9				1	0.03	1	
VERDE RIVER														
Source	13:55	22.5	11	226	232	8.45	264	Pos	0.02	0.017	137	0.3	24	
Normal	14:00	23	10	236	233	8.07	269	Neg	0.06	0.015	5.53	0.2	25	
Reverse Osmosis	14:10	23.5	1	14	6	6.98	7.72		0.01	< 0.002	0.53	0.02	2	
SINCLAIR WASH														
Source	17:35	9.1	47	42	56	7.10	444	Neg Pos			996	0.3	2	
Normal	17:40	9.6	58	46	60	7.13	461	Pos Neg			158	0.14	2	
Reverse Osmosis	17:50	9.7	2	10	6	7.30	15.6	Neg Neg			0.74	0.03	1	

Table D11- Water Quality Results of the Portable Water Treatment System

Note: Cells colored yellow were analyzed by an independent laboratory.

All samples taken on 4/9/2006

Blue text indicates a value outside of federal secondary drinking water standards.

Red text indicates level that violate federal safe drinking water standards.

Portable Water Treatment System

Appendix E Chain of Custody Records





	H D	Mark alrahum	RELINQUISHED BY (SIGNATU				- and -	PECKS-RO-2	PECKS N. 02	PECKS- 5-02		PECKS-RO-01	PECKS - N-01	Peck5-5-01	SAMPLE IDENTIFICATION	Mark Abraho	Moch alacher		Line Qual	GE Anal	Nort		/
	6	Mar	RE)					4/9/06	4/9/06	90/10/h		90/6/1	90/10/14	30/b/h	DATE	SIM	S		e 1955	ytical	est		000
	LUC	Le Abre	PRINT N					13:55	14.30 V	13:55		3:53	14:20	3:55	TIME	W WAST X OTHER SPECIFY:	A WATEF			(928)	2400 Flanst		
	Hr.L.	hams	AME					Verde	Jord	vorde		Verd	Verde	Verde	SAMP	EWATER	AMPLE TY			774-2312	East Hunt		
-	R OUT	AL	RECEIVED BY					River	River	River		CRIVER	River	RIVER	LE LOCATION	F FIELD BLANK	OOL GSLUDGE			• fax 774-6469	ington Drive		
	5	5	(SIGNA					-		-		-	_	-	NO	. CONTA	AINERS		FAX	TELEP	PERSC	CLIEN]
	8	K	TURE)					<	<	<	194	6	<	<u> </u>	GR	AB	E		3	HONE	ACT	D	
	R	Laure	-					\vee		12		0	0	>	SAI	MPLE T	YPE /ED		(83	10	See le	3	
			PRI												HN Na			242	243	PIGI			
		MJ.1	NT NAME											-	H ₂ HC	SO ₄	SE ONLY		230	55333	cham		
		N17													DO	HOL NOT AP	D		0		Â.		
	4.10.2	9-01-14	DATE					\times	×	×		×	×	×			ANAL		CONTR	PROJE	,	ADDRE	10110
	6160	54919	/ TIME							<i>a</i> .						$\langle \rangle$	YSES	• SEI	ACT NO.:	NN TO		SS	
SAMPLI	FAX															\geq		FEES		C			
NDARD	RESULTS		KS	10.10/14												$\langle \rangle$	$\langle \rangle$	CHED		ZA			, neces
OTHER	SPECIA							-							(DWR)			ULE ·	JOE P.O	- 984			
(SPECIFY)	L DETECTION														PWS / POE	AMENTO .	s		NO.:	PES			UATE
	LIMITS / REC							.56	56	.56		560	50	50	IDEN	11	AMPLE / C						
	DUIRE							0	OR	0		0	0		TIFICA	1.6	TURE						

Chain of Custody from from Nortest Analytical Laboratories

Portable Water Treatment System

Appendix F Operating Instructions







- Step #2 Turn OFF the MAIN Switch
- Step #3 Open the Inlet Filter Housing clean Filter Close Inlet Filter Housing
- Step #4 Insert the Rubber Stopper into the open end of the Suction Tubing
- Step #5 Store all tubing inside of Storage Case prior to transfer

Troubleshooting

If suction is lost:

Ensure that *Suction Tubing* is submerged in water Ensure that *Inlet Filter* is clear of debris - Clean if necessary Ensure that *Sediment Filter* is clean - Replace as necessary Ensure that *Pre-Carbon Filter* is clean - Replace as necessary

If flow rate is lower than expected:

Ensure that Inlet Filter is clear of debris - Clean if necessary Ensure that Battery is fully charged - Charge if necessary Ensure that Sediment Filter is clean - Replace as necessary Ensure that Pre-Carbon Filter is clean - Replace as necessary Check Post Carbon Filter flowrate after removing from system - Replace as necessary

Portable Water Treatment System

Appendix G Parts Inventory





Table G1 - Parts Inventory with Associated Cost

Part	Purpose	Qty	Wholesale Cost	Retail (Actual) Cost	Location Found				
Screen filter	Remove grit and gravel	1	\$2	\$3.00	Home				
Pump and motor	Provide the needed pressure and flow	1	\$75	\$85.00	Wind&Sun				
20 µm carbon cartridge	Prefilter to remove sediment	2	\$5	\$7.00	HomeDepot				
1 μm filter cartridge	Secondary filter providing greater removal	2	\$5	\$7.00	HomeDepot				
1µm carbon filter cartridge	Removes fine particles and improves taste	1	\$8	\$10	Online				
Blue filter housing	Holds filter cartridge	1	\$22	\$25	Lab				
Clear filter housing	Holds filter cartridge	1	\$20	\$29	Lab				
Needle valve	Controls recycle line flow	2	\$8	\$10	Lab				
Check valve	Prevents backflow into the RO filter	2	\$8	\$10	Lab				
Solenoid valve	Regulates hydraulic path of water	3	\$24	\$31	Home				
1/2" Polyethylene tubing	Holds pressure and flow through system	10 ft	\$2	\$4	HomeDepot				
1/4" Polyethylene tubing	Carries flow into and out of RC filter) 10 ft	\$2	\$4	HomeDepot				
UV filter	Disinfects water	1	\$60	\$80	Online				
Battery	Provides 35 amp hours of 12V DC power	1	\$45	\$49	Battery Plus				
Battery charger	Charges battery from a 120V source	1	\$25	\$29	Battery Plus				
Inverter	Converts 12V DC into 110V AC for UV lamp	1	\$15	\$20	Battery Plus				
Pressure gage	Measure pressure inside pipe	1	\$10	\$12	ENE Lab				
Fittings	Adapts tubing to filter housings, valves, and pump	28	\$56	\$90	Multiple Locations				
Electronic parts and wires	For conductivity sensors, solenoids and power	NA	IA \$15 \$26		Radio Shack				
RO filter	Removes metals and salinity	1	\$96	\$109	Online				
RO filter housing	Houses filter	1	\$76	\$84	Online				
Casing	Contains all parts	1	\$10	\$24	Other				
		Total	\$587	\$745					